GUIDE BOOK No. 8

TRANSCONTINENTAL EXCURSION C 1

Toronto to Victoria and return Via Canadian Pacific and Canadian Northern Railways

PART III

GEOLOGORUM CONVENTUS
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CANADA
MENTE ET MALLEO

ISSUED BY THE GEOLOGICAL SURVEY
OTTAWA, CANADA, 1913.

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VANCOUVER ISLAND.

BY

Charles H. Clapp.

INTRODUCTION.

The Vancouver Island excursions afford an opportunity to study the geology of a readily accessible area which is fairly representative of the whole Pacific Coast region of North America, and to examine the most important coal field of that region. Features of wide geological interest to be seen, are:—(1) Ancient volcanism, including flows and fragmental rocks, denuded volcanoes, fossiliferous tuffs, columnar jointing, and pillow structure. (2) Dynamic and contact metamorphism of basic volcanics and associated limestones producing marbles, amphibolites, and garnet-diopside-epidote rocks. (3) Batholithic and dyke intrusives, illustrating contact shatter-breccias, differentiation, sequence of the different phases of igneous activity, and origin of primary gneisses. (4) Sedimentation, illustrating unconformity, rapid lateral and vertical gradation, calcarenites, sandstone dykes, and coal. (5) Glaciation, grooves, striations, roches moutonnées, glacial and interglacial deposits, such as deltas with terraces and kettles. (6) Physiographic features, peneplain and monadnocks, glacial lakes and fiords, and various types of shore-lines. (7) Economic geology, contact deposits, coal and other non-metallic materials.

GENERAL GEOLOGY AND PHYSIOGRAPHY.

Vancouver island (**4**) is one of the border ranges of North America and is separated from the mainland by the submerged northern portion of the great marginal depression of North America, known as the Pacific Coast downfold (**17**). This depression is flanked on either side by great mountain ranges; in British Columbia by the Coast range to the east and the ranges of Vancouver island and Queen Charlotte islands to the west. The Vancouver range, which virtually constitutes Vancouver

island, trends N. 55° W. The entire island is 290 miles (470 km.) long and 50 to 80 miles (80 to 130 km.) wide, the total area being about 14,000 square miles (36,000 sq. km.). It is, as stated, separated from the Coast range of the mainland by the submerged northern end of the Pacific Coast downfold, which is occupied from south to north by Haro, Georgia, Johnstone, and Broughton straits and Queen Charlotte sound. It is separated from the mainland to the south, that is from the Olympic mountains of Washington, by a smaller transverse downfold, striking about N. 70° W., now occupied by the Strait of Juan de Fuca.

Vancouver island is composed of deformed metamorphic, volcanic and sedimentary rocks, intruded and replaced by numerous irregular bodies of granitic rocks, and fringed along both coasts with fragmental sediments, which rest unconformably upon the metamorphic and granitic rocks. The metamorphic rocks are largely of lower Mesozoic age, presumably upper Triassic and lower Jurassic, but they may include some Palæozoic members. Apparently the oldest rocks, considered provisionally as of late Palæozoic (Cariboniferous) age, are a series of slates and quartzose schists, with some fragmental volcanic members. This series extends across the southern end of the island and is called the Leech river formation.

The lower Mesozoic rocks comprise the larger part of Vancouver island, and constitute the Vancouver group. They consist chiefly of metamorphosed basic volcanics, principally meta-andesites, the Vancouver volcanics. Certain schistose and more salic volcanic rocks are apparently interbedded with the Leech river formation, but the typical meta-andesites, although separated from the Leech river formation largely by faults, are apparently younger and unconformable. Associated with the Vancouver meta-andesites and occurring chiefly in small intercalated lentils, is a formation of limestones called the Sutton formation. Besides the limestones, there is associated with the meta-volcanics a series, of stratified slaty and cherty rocks, the Sicker series, composed partly of volcanic material. These rocks and their associated volcanics have been greatly metamorphosed and converted into schists.

All of the above mentioned rocks are intruded and partly replaced by batholithic and dyke (minor intrusive) rocks.

The batholithic rocks are chiefly granodiorite with marginal facies of diorite, but in the southeastern part of the island there is a large batholith of gabbro-diorite and quartz-diorite gneisses. All of the batholithic rocks are closely related and appear to have been irrupted during the same general period of intrusion. Nevertheless they may be subdivided into four types that were irrupted in a definite sequence, apparently as follows:—Wark gabbro-diorite gneiss, Colquitz quartz-diorite gneiss, Beale diorite, and Saanich granodiorite. It is probable that all the 'minor intrusives' also, salic and femic porphyrites, were irrupted during the same general period.

Unconformable upon an erosion surface of the metamorphic and granitic rocks, and confined for the greater part to the east coast of the island, is a thick conformable series of fragmental sediments, the Nanaimo series, largely of upper Cretaceous age. It consists of conglomerates, sandstones, and shales, with some coal. In general, it has been deformed, into broad open folds with a northwest-southeast strike, and a general northeast dip, but in places it has been closely folded, overturned to the southwest and broken by reversed and overthrust faults.

The deformation of the Nanaimo series probably occurred in post-Eocene times. Previous to it, during upper-Eocene times, a thick formation of volcanic rocks, the Metchosin volcanics which are chiefly basalts, was accumulated in the southern part of the island. These volcanics were involved in the post-Eocene deformation, and at the same time were intruded by stocks of gabbro, the Sooke gabbro, which ranges from a femic to a salic gabbro and even to true anorthosite.

In later Tertiary time during the erosion cycle initiated by the post-Eocene deformation, the Vancouver range was reduced to a subdued surface, which in its southern part was a peneplain with a few monadnocks remaining a few hundred feet above the general level. In its central part, however, the surface was one of considerable relief, with larger and higher monadnocks and small ranges of mountains. During this cycle a large part of the detritus was deposited off the southern and western coasts of the island against a submerged mountainous slope, and formed a coastal plain, composed largely of coarse conglomerates and sandstones, the Sooke and Carmanah formations. The subdued and peneplained Tertiary erosion surface and the coastal plain

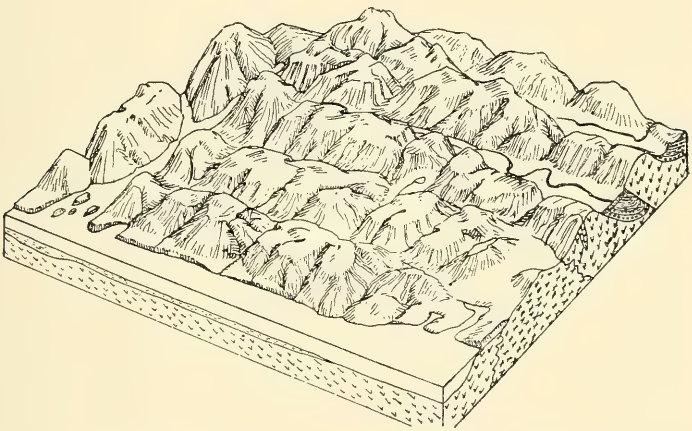
Southern part of Vancouver range, showing uplifted and dissected Tertiary peneplain, with few and relatively low monadnocks. Southern part of Malahat district, looking northwest from Mt, Shepherd.

deposits were subsequently uplifted, presumably during Pliocene times, and were then dissected during a pre-Glacial cycle, initiated by the uplift. Over the larger part of the island, the dissection, which was presumably accomplished by revived, large, transverse streams with subsequent tributaries, reached a stage of maturity, and the Tertiary peneplain and subdued surface is still preserved in the wide, relatively smooth interstream areas. The present elevation of the uplifted Tertiary peneplain is less than 1,500 feet (450. m.) near the southern coast, but increases rapidly to the northwest, so that in the central part of the island, the elevation of the uplifted subdued surface is about 4,000 feet (1200 m.), while the old residuals are now since uplift, 5000 to 7,000 feet (1,500 to 2,100 m.) above sea level, a few peaks being even higher.

In the southeastern portion of the island, although the region is largely underlain by crystalline rocks of the same character as the rest of the island, the dissection was carried to a further stage, that of late maturity to old age, so that the Tertiary peneplain was entirely destroyed and another subdued surface was developed several hundred feet lower, now averaging about 100 feet (30 m.) above sea level, but surmounted by numerous relatively small monadnocks. The sedimentary rocks along the coasts, the Nanaimo series along the east coast and the Sooke and Carmanah formations along the west coast, being less resistant than the crystalline rocks which form the larger part of the island, were also, reduced during the pre-Glacial cycle to a lowland, exposing the mountainous slope against which the Sooke and Carmanah formations were deposited. These latter formations were, after further uplift, also retrograded so that now mere remnants of the former Tertiary coastal plain exist, fringing the southern and western coast of the island. It seems as if at some time following the mature dissection of the uplifted Tertiary peneplain and the development of the lowlands, the southeastern portion of the island was depressed in part below sea-level, drowning the valleys, but leaving the higher elevations as islands and promontories, and thus forming the irregular drowned coast characteristic of that part of the island.

In Pleistocene times, Vancouver island was apparently smothered by a thick ice-cap, which smoothed and rounded all the mountains under 4,000 or 5,000 feet (1,200 to 1,500 m.) high, while the pre-Glacial valley heads in the higher

mountains were excavated by local glaciers, so that these high mountains now have characteristic serrated summits. Valley glaciers occupied and scoured out the larger valleys, converting some of them, chiefly the transverse valleys flowing southwestward from the main range to the Pacific, into fiords, and deepening some of the interior valleys into large lake basins. The valley glaciers flowing eastward from the east slope of the Vancouver range joined with



Block diagram, illustrating topography of southern Vancouver island.

the larger and more numerous glaciers flowing westward from the range of the mainland, and formed an extensive piedmont glacier which occupied the downfold between the Vancouver range and the ranges of the mainland. The southward flowing portion of this piedmont glacier, [8] called the Strait of Georgia glacier, overrode the lowland developed by the pre-Glacial cycle in southeastern Vancouver island and sub-maturely glaciated it. On the retreat of the earlier and larger glaciers of the Admiralty epoch, the land stood at least 200 feet (60 m.) lower than at present, and during an inter-glacial epoch, the Puyallup, the lowlands developed by the pre-Glacial cycle were covered by marine and delta deposits composed largely of glacial detritus, the Maywood clays and Cordova sands and gravels. During a later and less intense epoch of glacial advance, the Vashon, the inter-glacial deposits were

partially eroded by the smaller glaciers. The apparently rapid retreat of the Vashon glaciers left the inter-glacial deposits partly covered by a younger drift and by large delta deposits, the Colwood sands and gravels, built at the front of the larger retreating valley glaciers.

A recent uplift of some 250 feet (75 m.) has caused a partial recovery from the former depression, which, as mentioned above, resulted in the drowned coast of south-eastern Vancouver island, and has initiated the present marine cycle. During this cycle the uplifted Pleistocene deposits have been retrograded to form steep cliffs some 250 feet (75 m.) high, while the coast, where composed of the crystalline rocks, presents the initial irregularities of the drowned glaciated surface. Inland the uplifted Pleistocene deposits have been terraced by the streams revived by the uplift, and the larger of the revived streams have cut narrow canyons, from 100 to 300 feet (30 to 90 m.) deep, in the hard rock.

ANNOTATED GUIDE.

VANCOUVER TO VICTORIA.

(Excursion C 1, and C 2, Section 1.)

Miles and Kilometres.

0 m.
0 km.

Vancouver—Leaving Vancouver the steamer sails westward through the narrow pass, called the First Narrows, at the entrance of Vancouver harbour, into the Strait of Georgia. To the north are the lower mountains of the Coast range, composed largely of granitic rocks, and to the south is the low area underlain by the relatively unresistent Eocene sediments, consisting largely of sandstones and conglomerates, only moderately disturbed, and well exposed in the shore cliffs [**9**]. The Eocene sediments are almost entirely covered with the thick deposit of clay, sand, and gravel comprising the Fraser River delta, built largely in post-Glacial times and recently uplifted some 400 feet (120 m.) and cliffed during the present marine cycle so that the old delta appears conspicuously

Miles and Kilometres.

to the east as the steamer sails south in the Strait of Georgia. The present delta of the Fraser forms an extensive lowland, only a few feet above sea level, that extends southwest from the older, uplifted delta.

To the west is Vancouver island, a good general view of which may be had in clear weather. The dark mass of the Vancouver range, composed largely of metamorphic and crystalline rocks, steeply surmounts the coast lowland, underlain by the less resistant sediments of the Nanaimo series. Most of the summits of the Vancouver range are rounded or ridge-like, but a few snow capped and serrated peaks are seen crowning the whole.

44 m. 71 km. **Active Pass**—Leaving the open Strait of Georgia the steamer enters Active Pass and for the next 25 miles (40 km.) sails through the relatively narrow, but deep, channels between the small islands off the southeast coast of Vancouver island. Active pass affords a section across the northeastward dipping upper members of the Nanaimo series, and is doubtless the result of the mature glaciation of a transverse pre-Glacial valley by one of the rapidly moving tongues of ice forced southward across the valley by the large southward-flowing Strait of Georgia glacier (**8**). An example of the rapid lateral gradation of the Nanaimo sediments, Northumberland formation [**5**], is here seen. To the northwest of the central part of the pass, on Galiano island, the sediments are chiefly conglomerates with some sandstones, while to the southeast along the line of strike on the shores of Mayne island in Miners bay, the same horizon consists chiefly of sandy shales, although there is no offset in the Pass. Since the dip of the sediments is about 20 degrees to the northeast, the northeast or back slopes of the islands have a cuesta form and are comparatively gentle, while the southwest or front slopes are steep.

Crossing Trincomali channel, which is a drowned longitudinal anticlinal valley, the

Miles and Kilometres.

steamer enters Swanson channel between Prevost island on the northwest and Pender island on the southeast On these islands, the Nanaimo sediments, which are stratigraphically of a lower horizon than on Galiano and Mayne islands, are rather closely folded so that the dips are variable and fairly high. Seen in the background to the south and west of Prevost island is Saltspring island, the largest of the many islands off the east coast of Vancouver island. Its southern and central part is composed largely of the metamorphic rocks of the Vancouver group with intrusive bodies of granodiorite. Upon these the Nanaimo series lie unconformably, the basal members being stratigraphically considerably above the base of the series in other localities. The metamorphic and granitic rocks are seen surmounting the Nanaimo sediments, attaining an elevation of about 2,300 feet (700 m.), although the average elevation of the comparatively smooth top, which is a part of the uplifted Tertiary peneplain, is about 1,500 to 1,800 feet (450 to 540 m.). A low valley underlain by Nanaimo shales crosses the upland, and is bounded on the north by a steep slope. This slope, which is underlain by the metamorphic rocks with a cap of basal conglomerates, has been developed along an old fault, which separates the Nanaimo shales from the upthrown metamorphics. The original fault scarp was destroyed during the Tertiary erosion cycle, but after the uplift of the Tertiary peneplain, the less resistant Nanaimo sediments were more rapidly eroded leaving the metamorphics again in relief and producing a new scarp, a fault line scarp along the old fault.

Leaving Swanson channel, the steamer enters Moresby passage between Portland island to the west and Moresby island to the east. Both islands consist largely of the older metamorphics (Sicker series) and intrusive granodiorites, although small areas of Nanaimo sediments rest unconformably upon these older

Miles and Kilometres.

rocks. Farther to the northwest the same rocks form the southern part of Saltpsring island, whose southern slope is another fault line scarp, developed along a reversed strike fault parallel to that described above, and which has thrust the metamorphics against the Nanaimo sediments to the south. These sediments, which are folded into a closed syncline, overturned to the southwest, are exposed on the small islands to the south of Moresby passage, among which the steamer sails.

Leaving these islands the steamer enters the more open waters of Bayan bay. To the west is the town of Sidney, on the southeastern lowland of Vancouver island. This lowland, called here the Saanich peninsula, since it is separated by Saanich inlet from the upland of Vancouver island is underlain by the Saanich granodiorite, most o which is greatly fractured and altered. A less fractured portion of the granodiorite forms Mt. Newton, altitude 1,000 feet (305 m.), the largest monadnock of the vicinity, seen conspicuously to the southwest of Sidney. The sky-line of the upland which is the result of the mature-dissection of the uplifted Tertiary peneplain, is fairly even, the only pronounced irregularities being the large steep-sided valleys and occasional small monadnocks.

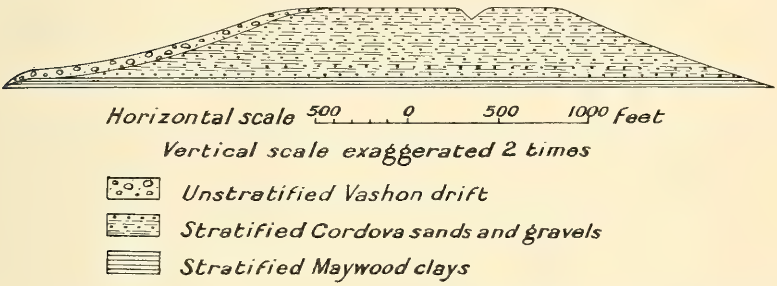
From Sidney channel between James island on the west and Sidney island on the east, the glacial deposits which mantle much of the southeastern lowland of Vancouver island are seen. Indurated rocks are not exposed on James island, and on Sidney island are exposed only in the southern part. The deposits, consisting of Maywood clays covered by Cordova sands and gravels, are chiefly inter-glacial and largely of marine origin. At the northern end of Sidney island is a brick plant which uses the Maywood clays. The inter-glacial deposits are strewn with large glacial boulders and are partly covered by the younger Vashon drift They were in part eroded during the Vashon

Miles and Kilometres.

glacial epoch, and upon the retreat of the Vashon glaciers the uneroded portions of the inter-glacial deposits were left as long, nearly straight, esker-like ridges, their axes having a general strike of S. 25° E. Since the retreat of the Vashon glaciers and the comparatively recent uplift these deposits have been rapidly retrograded into the steep cliffs about 100 feet (30 m.) high, which are seen on both James and Sidney islands. The retrograded material has been carried northward by the prevailing shore currents, building the long spits and beaches that are seen extending north from Sidney island. As the steamer leaves Sidney channel, the mature southern shore of James island is seen. Here the inter-glacial deposits have been retrograded, presumably for over a mile, resulting in a straight shore line with nearly vertical cliffs, which in the central portion is over 200 feet (60 m.) high. An idea of the rapidity of the retrogression of this shore is shown by a wire fence, which in 1907 was built to the edge of the cliff and which in 1910 had been undermined for 24 feet (7·3 m.) apparently not all at once but gradually, as that part of the cliff was retrograded uniformly with the rest. It is improbable however, that the entire shore-line is being retrograded at the rate of 6 feet (1·8 m.) a year, but the rate is doubtless more than one foot (0·3 m.). As a result of this retrogression a good section of the till-covered deposits is obtained, affording a proof of their inter-glacial origin, and of the fact that the inter-glacial drift ridges are erosion remnants of once more extensive deposits and are not constructional forms, since the outline of the present surface of the ridge cuts sharply across the bedding of the deposits. The southern shore of Sidney island is in marked contrast to that of James island, for on Sidney island the drift which doubtless originally covered the hard rocks, has been largely removed and a very irregular shore-line, still in an early stage, is the result. This has been called,

in order to show its analogy to a superposed valley, a contraposed shore-line.

Leaving Sidney channel, the steamer enters Haro strait between Vancouver island and San Juan island. To the east, the small D'Arcy islands, composed of the Vancouver volcanics, are seen, and to the west the retrograded inter-glacial deposits covering the south-eastern part of the Saanich peninsula. To the



Section exposed along the south shore of James island, illustrating relation of superficial deposits.

southwest is a conspicuous monadnock, Mt. Douglas, altitude 725 feet (220 m.), which surmounts the lowland developed in the vicinity of Victoria.

Leaving Haro strait, the steamer passes between Vancouver island and several small islands, Discovery, Chatham, and Chain islands, which are composed largely of the Wark gabbro-diorite gneiss. Turning westward from these islands towards Victoria harbour the route follows for a short distance the great transverse downfold occupied by Juan de Fuca strait which lies between Vancouver island and the Olympic mountains to the south. The Olympic mountains, which are composed largely of pre-Tertiary metamorphics similar to the metamorphic rocks of Vancouver island fringed by upper Eocene basalts and Miocene sediments [**2** and **14**], seem to rise abruptly from sea-level to elevations of 6,000 to 8,000 feet (2,000 to 2,500 m.), their serrated peaks

Miles and Kilometres.

covered with large glaciers and snow fields. To the east on clear days may be seen the Cascade range of Washington with the denuded snow-and glacier-capped volcano, Mt. Baker, towering above the highest peaks for 4,000 feet (1,200 m.) and attaining an elevation of 10,694 feet (3,260 m.) To the northwest, the comparatively low, flat-topped, heavily wooded range of Vancouver island, attaining elevations from 1,500 feet (450 m.) to 3,000 feet (900 m.), forms the background, while in the foreground is the pre-glacial lowland of the vicinity of Victoria, surmounted by many small monadnocks.

Rounding Trial islands which ar composed of the Vancouve: meta-andesites, the steamer gradually turns northward and finally enters Victoria harbour, a comparatively narrow and small inlet, formed by the depression below sea-level of one of the submaturely glaciated valleys of the southeastern lowland. To the east is the city of Victoria, and to the west is the Esquimalt peninsula.

84 m. 135 km. **Victoria—**

GEOLOGY OF THE REGION AROUND VICTORIA.

Physiography.

The region around Victoria [4] consists almost entirely of the lowland developed in the southeastern part of Vancouver island during the pre-Glacial cycle. The lowland is not smooth, but, except where covered by drift deposits, is characterized by small irregular valleys and by a great number of rock ledges. The valleys are well adjusted to the weaker parts of the rocks, shear zones and joint planes, and frequently follow contacts, even where the contacts are irregular. The lowland is drained chiefly by numerous wet-weather streams with an intermittent flow, there being no larger rivers. Surmounting the lowland from 100 to 600 feet (30 to 180 m.) are numerous but relatively small monadnocks, and in the western part

of the region is an upland transitional in character between the lowland and the upland of the Vancouver range, formed, as described, only by the mature dissection of the previously uplifted Tertiary peneplain. In the upland portion of the region around Victoria, the dissection of the Tertiary peneplain reached a further stage, one of late maturity, in which virtually, all of the uplifted peneplain was destroyed, although the region retains considerable relief. The monadnocks do not correspond with the outlines of the various rock formations, but have survived where the rocks were less fractured and sheared or less altered. Most of the monadnocks are roughly conical, but some are elongate, corresponding with the trend of their component rocks.

It was upon the lowland that the stratified drift was deposited during the inter-glacial period, the lowland having been previously scoured off by the southward flowing, piedmont, Strait of Georgia glacier, so that the elevations are now knob-like, with relatively smooth, rounded outlines. During the second period of glaciation, the stratified drift was partially eroded. This left long, esker-like ridges in the lea of some of the monadnocks, and in some of the eroded hollows in the drift mantle small lakes such as Swan and Lost lakes. In the upland portion the scouring action of the glaciers is more evident, especially of those valley glaciers that were confined between the sides of deep valleys, and here there are small lakes in deepened rock basins. Since the recent uplift the drift deposits have suffered little erosion, although in the western part of the region they have been terraced. In this locality the drift forms a wide, flat plain, from 200 to 250 feet (60 to 75 m.) above sea-level, known as Colwood plain.

It was apparently the depression of the glaciated and drift-covered lowland with numerous monadnocks, followed by a partial recovery, that formed the present irregular shore line and the numerous islands of the region. The initial shore line must have been rather simple, with smooth flowing outlines where the crystalline rocks were drift covered, but with many small, rounded and smoothed irregularities where the glaciated rock surfaces were not drift covered. During the present marine cycle, the shore has been subjected to moderately strong erosion, and the uplifted drift deposits have been rapidly retrograded to

form sea-cliffs 200 to 250 feet (60 to 75 m.) high with sand spits and bars, and in some places, as on the shore of Royal Roads, a nearly straight shore line. In many instances, as along the shore south of Victoria, the drift has been retrograded in places beyond the underlying rocks. The hard rocks form small, sub-sharp to rounded points, which project beyond the even, cliffed shore line. In other instances, as on the shore of Esquimalt peninsula, the drift has been largely removed, or else was never deposited and a very irregular shore line is the result. This irregular shore line, developed by retrogression of the drift cover, is in marked contrast to the simple retrograded type,and as already mentioned, in order to emphasize its analogy to the valley of a superposed river, has been called a contraposed shore line. The larger part of the coast is composed of resistant rocks, and virtually none of the initial irregularities of the depressed glaciated rock surface have been destroyed. On the contrary minor irregularities, such as small coves and wave chasms have been developed by wave action on the shear zones, joints, dykes, and interbedded softer rocks. The hard rocks themselves have not been beached, but since the retrograded drift deposits frequently occur between head lands of hard rock, narrow beaches composed of their material occur in the protected places of the headlands.

General Geology.

TABLE OF FORMATIONS.

Quaternary.

Superficial deposits.

Post-Glacial deposits	Recent.
Beach alluvium	
Valley and Swamp alluvium.	
Vashon Glacial deposits.	Pleistocene, later Glacial epoch.
Colwood sands and gravels	Stage of glacial retreat.
Vashon drift.	Stage of glacial occupation.
Puyallup inter-Glacial deposits.	Pleistocene.
Cordova sands and gravels	Inter-glacial epoch.
Maywood clays.	
Admiralty Glacial deposits.	Pleistocene.
Admiralty till.	Earlier Glacial epoch.

Shore south of Victoria, looking east to Finlayson point, showing development of contraposed shore-line. Hard rocks overlain by retrograded Vashon drift and Maywood clays.

	Tertiary.	
Metchosin volcanics.	Upper Eocene.	Ophitic basalt flows tuffs and agglomerates, with intrusive diabase dykes.
	Mesozoic.	
Batholithic and minor intrusives	Upper Jurassic and possibly Lower Cretaceous, correlated with Coast Range batholith.	
Diorite porphyrite		Dykes.
Saanich granodiorite		Stocks.
Colquitz quartz-diorite gneiss		Batholith of quartz--diorite gneiss, and quartz-feldspar (salic) and hornblendite (femic) facies, usually interbanded.
Wark gabbro-diorite gneiss.		Batholith of gabbro--diorite gneiss, with unfoliated gabbro and salic gabbro facies.
Vancouver group.	Jurassic and Triassic.	
Sutton formation.	Lower Jurassic possibly including Triassic.	Lentils of crystalline limestone in Vancouver volcanics.
Vancouver volcanics.	Lower Jurassic possibly including Triassic.	Metamorphic andesites, basalts, and olivine basalts, porphyries, amygdaloids, tuffs, and agglomerates and intrusivedykes and sills of basalt and andesite porphyrites.

Vancouver group—The metamorphic rocks of the region around Victoria are the Vancouver volcanics and the Sutton limestones, both of the Vancouver group and presumably of lower Mesozoic age. The Vancouver volcanics, the more important formation, consist largely of metamorphic flow rocks of medium basicity, meta-andesites, and some meta-basalts. Interbedded with the flow rocks are amygdaloids, and fragmental volcanics, tuffs and agglomerates, and cutting them all are dykes and sills of basalt porphyrite. All of the volcanics have been metamorphosed and greatly altered, the secondary

minerals being chiefly uralite, chlorite, epidote, calcite, and sericite. Such alteration is similar to that which takes place under conditions of moderate to shallow depths and moderate temperatures, and probably took place during the folding and shearing that the volcanics suffered in orogenic periods. However, near the contacts with the intrusive granitic rocks the volcanics have been greatly contact metamorphosed and some of them have even been recrystallized or replaced, forming various metamorphic types such as silicified and feldspathized varieties, amphibolites, and even garnet-diopside-epidote rocks. Analyses of the two last types are given below. The volcanics are also seamed with veins of quartz and of quartz and epidote, and in places are impregnated with metallic sulphides, chiefly pyrite.

	1.	2.
SiO_2	51·60	42·86
Al_2O_3	15·00	7·19
Fe_2O_3	1·85	14·24
FeO	8·48	4·28
MgO	7·15	2·96
CaO	7·63	26·30
Na_2O	3·09	0·27
K_2O	0·70	0·33
H_2O+	1·95	1·00
TiO_2	2·00	0·30
P_2O_5	0·18	0·21
MnO	0·24	0·50
	99·87	100·44
Specific gravity	2·95	3·44

1. Amphibolite, Iron Mask Mineral claim, south of Mill hill, Esquimalt district. M. F. Connor, analyst.

2. Garnet-diopside-epidote rock, Iron Mask Mineral claim, Mill hill, Esquimalt district. M. F. Connor, analyst.

The Sutton formation is composed of crystalline limestone or marble, occurring as lentils intercalated in the Vancouver volcanics throughout their entire thickness. The lentils are small, only one of them, namely that extending from Esquimalt harbour west to Colwood plain, being over a mile long. The crystalline limestones are gray to grayish blue to white, compact to medium grained, and

where unmetamorphosed are composed almost entirely of calcium and magnesium carbonates, the former greatly predominating. The only impurities are small amounts of argillaceous and carbonaceous matter and pyrite. Near the intrusive granitic rocks the Sutton limestones have been contact metamorphosed into light coloured, coarsely crystalline marbles carrying diopside and wollastonite, and even into garnet-diopside-epidote rocks and silicified and mineralized varieties.

The following analysis is of a sample of limestone from Rosebank Lime Company's quarry half a mile west of Esquimalt harbour by F. G. Wait of the Department of Mines.

$CaCO_3$	95·35
$MgCO_3$	2·85
$Fe_2O_3+Al_2O_3$	0·16
Insol	1·95
S	tr.
P	tr.
	100·31

The Sutton limestones and Vancouver volcanics are in general contemporaneous and conformable, the limestones probably having been built by marine organisms that lived on the shores of volcanic islands formed during the eruption of the Vancouver volcanics. However, the actual contacts between the two formations are intrusive, the volcanics cutting the limestones. The intrusive contacts, which are also observed between the volcanic rocks themselves, do not indicate that the limestones are an older formation or necessarily occur near the base of the Vancouver volcanics, but merely indicate that intrusive volcanic types occur intermingled with the limestones as well as with one another.

The Vancouver volcanics and Sutton limestones have been greatly deformed, doubtless largely during the upper Jurassic orogenic period. The general strike of the rocks, which on account of their massive character were, for the greater part, presumably warped into large folds, is about N. 80° W., and the dips are usually steep. The original bedding of the rocks is almost completely obscured, but the rocks are foliated, and the foliation and bedding appear

to be virtually conformable. In some instances the foliation is nearly north to south, which indicates that small folds occur. The rocks have also yielded by fracturing, shearing, and faulting.

During and following the upper Jurassic orogenic period, the Vancouver volcanics and Sutton limestones were invaded by granitic rocks and their accompanying minor intrusives, and at the contacts the volcanics were greatly shattered, cut by apophyses, and, as mentioned, greatly metamorphosed. The granitic rocks may be subdivided into three main types, irrupted in a definite sequence as follows: Wark gabbro-diorite gneiss; Colquitz quartz-diorite gneiss; and Saanich granodiorite. The minor intrusives, most of which accompanied the irruptions of the Saanich granodiorite, consist of dykes and small injected bodies of diorite porphyrites.

Batholithic and minor intrusives.

The Wark and Colquitz gneisses form virtually a single batholith, with a general northwest-southeast strike, corresponding with the strike of the Vancouver volcanics. The Wark gneiss is a dark greenish rock of medium to coarse grain and gneissic texture, consisting essentially of light greenish weathering plagioclase (labradorite-andesine) and hornblende, and since it is intermediate in composition between a gabbro and a diorite is classed as a gabbro-diorite. The following is an analysis of a typical sample.

SiO_2	48·68
Al_2O_3	18·05
Fe_2O_3	3·41
$Fe\,O$	6·44
$Mg\,O$	2·82
$Ca\,O$	10·00
Na_2O	3·18
$K_2\,O$	1·60
$H_2\,O+$	2·40
$Ti\,O_2$	0·80
P_2O_5	2·01
$Mn\,O$	0·20
	99·59
Specific gravity	2·91

Wark gabbro-diorite gneiss. One half mile south of Mt. Tolmie, Victoria district. M. F. Connor, analyst.

Fine grained phases of the Wark gneiss occur as segregations or inclusions in the normal rock, especially near the contacts with the intrusive Colquitz gneiss and Saanich granodiorite. In places they form bands parallel to the foliation, but more commonly they form irregularly shaped masses sometimes several yards in width, which frequently are elongated in a direction transverse to the foliation. The normal gabbro-diorite is not only gneissic but considerably altered and more or less metamorphosed, especially near the contacts with younger granitic rocks, where there have been developed certain metamorphic varieties with large and frequently poikilitic hornblendes or varieties in which recrystallized hornblende greatly predominates.

The Colquitz gneiss is a gray, medium grained rock of gneissic to schistose texture, consisting essentially of altered plagioclase (andesine), quartz, hornblende, and biotite, and is classed as a quartz diorite although it contains much more quartz than the average quartz diorite. At one locality the gneiss is a biotite granite. The Colquitz gneiss has also certain salic and femic facies. The salic facies is light coloured, consisting essentially of quartz and feldspar, while the femic facies is dark, consisting almost entirely of hornblende, thus forming hornblendites. The facies commonly occur interbanded, the separate bands or masses varying from a fraction of an inch up to several feet in width, thus producing a conspicuously banded gneiss. The larger femic bands are virtually always coarsely crystalline.

The following analyses are of the Colquitz gneiss:—

	1	2	3
$Si\ O_2$........	64·04	75·02	38·80
Al_2O_3.......	15·83	13·90	12·50
Fe_2O_3.......	2·16	0·45	6·57
$Fe\ O$........	2·40	0·40	8·20
$Mg\ O$.......	2·72	0·10	13·10
$Ca\ O$.......	3·60	1·16	11·42
Na_2O.......	3·52	3·06	1·60
$K_2\ O$........	1·43	5·37	0·81
$H_2\ O+$......	1·60	0·95	2·85
$Ti\ O_2$.......	0·30	0·04	1·60

P_2O_5	1·56	0·15	1·26
Mn O	0·15	0·10	0·23
	99·31	100·70	98·94
Specific gravity	2·74	2·63	3·16

1. Unbanded Colquitz quartz-diorite gneiss, Smiths Hill, Victoria district. M. F. Connor, analyst.

2. Salic facies of Colquitz gneiss, north of Prospect lake, Lake district. M. F. Connor, analyst.

3. Coarse grained facies (hornblendite) of Colquitz gneiss. Northwest of Prospect lake, Lake district. M. F. Connor, analyst.

The youngest granitic rock, the Saanich granodiorite, forms a stock underlying the southwestern part of Esquimalt peninsula, and other smaller stocks. It is a light coloured, medium-grained rock, frequently having a somewhat gneissic texture and consisting essentially of feldspar, orthoclase and andesine, quartz, and accessory hornblende, and usually biotite. The granodiorite contains also numerous small rounded segregations, darker coloured than the normal rock and consisting chiefly of plagioclase and hornblende. An analysis of a rather basic phase of the Saanich granodiorite is given below.

SiO_2	62·64
Al_2O_3	17·75
Fe_2O_3	1·64
Fe O	3·44
Mg O	2·53
Ca O	4·44
Na_2O	3·53
K_2O	2·14
H_2O+	1·65
TiO_2	0·60
P_2O_5	0·25
Mn O	0·14
	100·75
Specific gravity	2·71

Saanich granodiorite, south shore of Shoal harbour, North Saanich district, M.F. Connor, analyst.

The diorite porphyrites usually form fairly well defined and regular dykes, from a few inches up to 50 feet (15 m.) in width, largely confined to the vicinity of the contacts of the Esquimalt stock. They are greyish green, porphyritic rocks, with an aphanitic groundmass and phenocrysts of feldspar, hornblende, and sometimes augite.

All of the irruptive rocks have been more or less foliated, the gneisses greatly. The strike of the foliation is predominantly northwest-southwest, generally near N. 60° W, but varies widely. The rocks are also greatly jointed and fractured, and in places sheared. They are altered and, especially near the shear zones, are mineralized and cut by small and irregular quartz and quartz-epidote veins, but contain no mineral deposits of commercial value.

Although the Wark and Colquitz gneisses form virtually a single batholith, the Colquitz gneiss is distinctly intrusive into the Wark gneiss, the contacts being marked by wide zones of shatter breccias and numerous aplitic and a few pegmatitic apophyses of the Colquitz gneiss. Although in places cross cutting, the apophyses are usually injected parallel to the foliation, and are foliated themselves parallel to their walls. In some instances the apophyses, parallel to the foliation, are so numerous as to convert the gabbro-diorite gneiss into a banded gneiss resembling the banded Colquitz gneiss. Also the Wark gneiss is cut by large masses of the Colquitz gneiss, usually the salic facies, some of which are several hundred feet in width. The contact zones are sometimes sheared and foliated and the angular xenoliths of the gabbro-diorite gneiss in the quartz diorite gneiss have been pulled out into dark femic bands These strongly resemble the femic bands of the Colquitz gneiss, but in part perhaps differ from them by being occasionally broken or cut across the foliation by the quartz diorite. The relatively few dykes of pegmatite are unfoliated, and, while usually parallel to the foliation, are sometimes cross cutting.

The banded Colquitz gneiss, in particular that type with the wide, coarse grained, femic bands or masses, is more or less restricted in its occurence to the contacts with the intruded Wark gneiss. As described, its salic and femic bands vary in didth from a fraction of an inch to 4 or 5 feet (1·2 or 1·5 m.), and possibly to several feet.

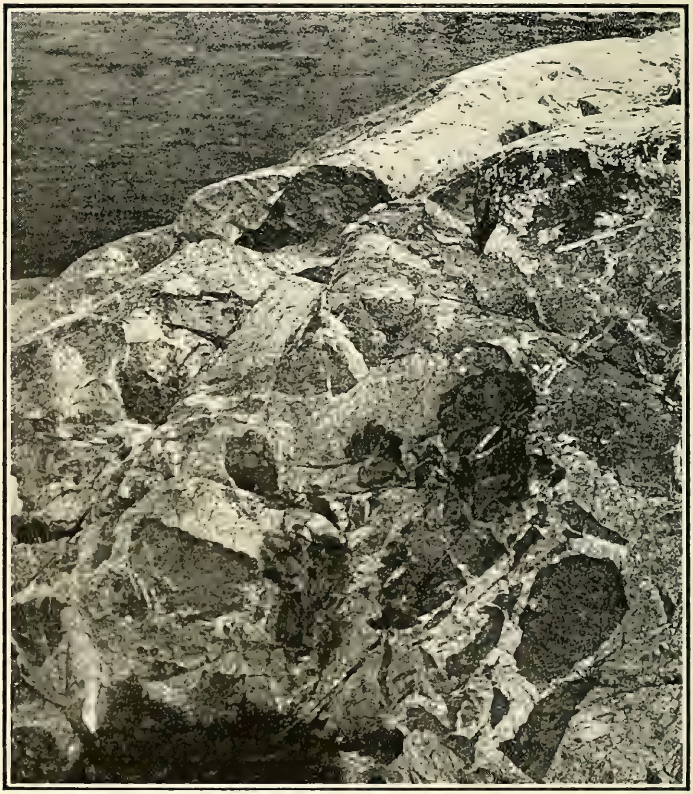
The length of the individual bands is more or less proportional to their width. Some of the bands, especially the narrower and finer grained, gradually pinch out, but others, notably the wider, coarser grained ones, end abruptly and irregularly. The sides of the bands are usually straight but are sometimes broadly curved and more rarely contorted. The contacts between the bands, while usually well marked, are not sharp in detail, but the crystals of one band are intergrown with those of the continuous bands. In places the Wark gneiss appears to be cut not only by salic apophyses of the Colquitz gneiss but by hornblendite apophyses, which seem to be intrusive and cross cutting. The relations however are so complex and the resemblance of the supposed hornblendite apophyses to the recrystallized Wark gneiss is so close that the intrusive nature of the hornblendite masses can not be positively affirmed. It is concluded that the banded Colquitz gneiss is of primary origin; that in part the salic and femic bands are true magmatic differentiates, the intrusive magma having been split into the salic and femic facies before it became too viscous for the separated facies to be pulled out into bands by continued movements in the differentiated magma; and that some of the wide, coarser grained bands are recrystallized and pulled out inclusions of the Wark gneiss.

The Saanich granodiorite is clearly intrusive into the Wark gneiss and doubtless is younger than the Colquitz gneiss. It brecciates the Wark gneiss, forming extensive areas of "contact complex", consisting of shatter breccias and networks of granodiorite and aplite apophyses in the gabbro-diorite gneiss.

The diorite porphyrites are younger than the granitic rocks. It is seen that the eruptive cycle, represented by all of the igneous rocks, the Vancouver meta-volcanics, the granitic rocks, and the diorite porphyrites, conforms to the general eruptive cycle, which consists of three phases of igneous activity in the following sequence: the volcanic phase; the batholithic phase; and the phase of minor intrusives.

The granitic rocks were irrupted into the rocks of the Vancouver group apparently in a relatively quiet manner, and have replaced them without disturbing them greatly. The invading magmas, even during their last active stages, shattered the invaded rocks along their contacts into angular fragments. Near the present contacts great

numbers of these fragments occur in the intrusive rocks but disappear within a few yards. They may have been shattered to smaller fragments and assimilated by the intrusive rocks while still in a magmatic condition, for of



Contact shatter breccia at contact of Wark gabbro-diorite gneiss and Saanich granodiorite, showing both angular and rounded xenoliths; ledge south of Outer wharf, Victoria.

this there is some evidence, or they have sunk in the intrusive magma to abyssal depths. Possibly it was by this last method that the granitic rocks replaced large volumes of the rocks into which they were intrusive.

As described, the granitic rocks were not irrupted at the same time, but during two main periods, which have

been called the Wark and Saanich periods. During the first period, the Wark and Colquitz gneisses were irrupted, but independently, thus dividing the Wark period into two sub-periods, the second sub-period being characterized by the irruption of a more salic magma than that irrupted during the first. The close relationship of the Wark to the Colquitz gneiss shows, however, that they are closely related in origin, and are doubtless differentiates of the same parent magma. A similar subdivision characterizes the Saanich irruptive period, but the first sub-period, during which the femic Beale diorite was irrupted, is not well represented near Victoria. Also the rocks irrupted during the Wark and Saanich periods are closely related structurally, and, except that those of the Wark period are gneissic, are similar lithologically. It is probable, therefore, that the Wark and Saanich magmas were themselves differentiates of the same parent magma, the Wark magma being more basic then the Saanich magma. Since the principal rock types have been separately, and more or less independently, intruded in large masses, the differentiation producing the various types must have been deep seated. Since the parent magma was apparently subdivided into the Wark and Saanich magmas, each of which independently underwent further differentiation under deep seated conditions, it seems probable that this differentiation did not take place in the same magma chamber. It looks as if the Wark and Saanich magmas after differentiation from the parent magma were irrupted from the primary magma chamber into separate chambers, where each underwent its further differentiation, producing the sub-types which were themselves irrupted independently into their present position. It also appears as if the three principal types were still further differentiated, apparently "in place", giving rise to the minor variations of the principal rock types.

Metchosin volcanics.—Confined to the western part of the region and separated from the other crystalline rocks by the thick deposit of sand and gravel of the Colwood delta, are the Metchosin volcanics. They are all basic, chiefly basalts and diabases, the latter occurring as dykes in the basalts. The basalts vary from coarsely porphyritic and ophitic varieties to amygdaloids, and frequently exhibit pillow and columnar structures. They are interbedded with fragmental varieties, ranging from fine tuffs

Pillow structure in Metchosin basalts. Islets off south shore of Albert head, Vancouver island.

to very coarse agglomerates. Some of the fragmental rocks are waterworn, and at least one bed of tuff is fossiliferous. The fossils, which are chiefly Eocene gastropods, give the only evidence of the age of the volcanics and place them definitely in the upper Eocene. The same fossil-bearing tuffs are found to the south on the Olympic peninsula [**14**]. It is probable that the eruptions of the Metchosin basalts were largely of a quiet nature from numerous fissures, and actual vents are doubtless represented by diabase dykes. That the eruptions were in part explosive is fully substantiated by the occurrence of agglomerates and tuffs, and it is possible that the irregular masses of coarse agglomerate represent the pipes or necks of old volcanic cones. The absence of terrestial sediments in the volcanics and the presence of marine organisms suggests that the volcanics were accumulated under marine conditions, presumably in deep water removed from any continental mass. But the occurrence of waterworn fragments and of marine fossils indicates that enough lava was erupted to form a platform which reached nearly to the surface of the water, and on which were built the cones that projected above sea level.

The Metchosin volcanics have been deformed and more or less altered. They have a general northwest-southeast strike and are evidently involved in several folds although the prevailing dip is about 30 degrees to the northeast. They are extensively sheared and faulted, and their northern contact is a profound thrust fault, which extends for 40 miles (64 km.) across the southern end of the island. Farther west they are also intruded by gabbro masses. The deformation and intrusion must have taken place at or near the close of Eocene times, for farther west the deformed and intruded rocks are unconformably overlain by Miocene sediments. Some of the alteration of the Metchosin volcanics must have taken place during the deformation, but much of it has taken place under surface conditions developing zeolites and similar secondary products.

Superficial Deposits—The drift deposits of the region are of varied character, having been deposited by various agencies during the different stages of glacial occupation and retreat [**7** and **8**]. The oldest of the superficial deposits, the Admiralty till, is confined to a few localities and occurs in the crevices and small irregular hollows of

the glaciated crystalline rocks, and is only a few feet in thickness. It varies from an unstratified, hard, yellowish gray, sandy clay, with subangular to rounded pebbles, to rudely stratified, coarser, yellow clayey sand, with scattered pebbles and subangular boulders.

The Puyallup inter-glacial deposits are chiefly well stratified clays, sands, and gravels usually found below elevations of 250 feet (76 m.) In general, the clays occur near the base of the deposits, and the sands and gravels near the top, so the deposits are subdivided into the Maywood clays and the Cordova sands and gravels. The Maywood clays are chiefly bluish or yellowish gray, sandy clays with numerous, irregularly distributed, subangular to rounded, undecomposed pebbles and boulders of crystalline rocks. They are well stratified and frequently contain layers of sand and occasionally of gravel. The clays are frequently carbonaceous, and plant impressions and remains are common in them. Impressions and occasional shells of marine organisms, chiefly small molluscs, are also found in them. The Maywood clays sometimes rest upon the Admiralty till, but more commonly lie directly on glaciated surface of the crystalline rocks. They vary greatly in thickness, depending partly upon the irregularities of the underlying rock surface, but they probably average as much as 100 feet (30 m.).

The Cordova sands and gravels consist of yellow to grayish yellow, medium to coarse grained, and usually pebbley sand, with irregular lentils and interbeds of gravel, and towards the base, interbeds sometimes 10 to 15 feet (3 to 4·5 m.) thick of sandy clay or rarely stiff blue clay. They also contain a few, irregularly distributed, small glacial boulders. The pebbles are usually fresh, but in some instances the coarser grained granitic pebbles have been entirely decomposed. The sands are well stratified,but are usually cross bedded, and exhibit instances of contemporaneous erosion and deposition. They also contain marine organisms, which are however very fragile. The Cordova sands and gravels, averaging 200 feet (65 m.) in thickness, overlie the Maywood clays, and usually form low ridges that were left in relief by the erosion of wide valleys between them by glaciers of the Vashon period Some of the ridges occur in the lea of the larger monadnocks.

The Vashon drift is ordinarily an unsorted till, with numerous undecomposed granitic boulders. In some places the finer materials of the drift are rudely stratified. Near the surface it is usually oxidized to dark brown, and passes into a dark, sandy and gravelly loam, which usually covers it. The drift seldom forms distinct and characteristic topographic features such as moraines, but is merely a mantle covering the crystalline rocks and the inter-glacial deposits. Below elevations of 250 feet (80 m.) except in restricted localities, the mantle is thin, seldom more than 3 or 4 feet (·9 to 1·2 m.) thick. Frequently it thins out so completely that over large areas it is absent or is represented only by glacial boulders, which are strewn over the surface of the inter-glacial deposits. Above elevations of 250 feet, (80 m.) the larger part of the entire drift mantle is the Vashon till, although it is probably mixed with more or less of the Admiralty till.

In the western part of the region is a deposit of sand and gravel about 200 feet (60 m.) thick, which forms a plain, the smooth Colwood plain, two to three miles (3 to 5 km.) wide and from 200 to 250 feet (60 to 80 m.) above sea level. On it are well defined terraces up to 20 feet (6 m.) high, and near its inner border are several kettle holes, the largest of which are 100 to 800 feet (30 to 250 m.) across and 10 to 80 feet (3 to 25 m,) deep. The deposit consists chiefly of coarse sands and gravels, which are well stratified and have a pronounced delta structure, the larger part of the deposit consisting of fore-set beds with dips of 15 to 25 degrees to the southeast. These are capped with 10 to 15 feet (3 to 5 m.) of top-set beds of horizontally stratified coarse gravels.

Since the superficial deposits described above are of glacial origin a discussion of their origin together with a description of the glaciation of the region is necessary. The lowland portion of the region was overridden by the southward flowing, piedmont, Strait of Georgia glacier. The results of the severe abrasion of the hard rocks by the glacier are most striking [7]. The rocks are not only smoothed, but are striated and grooved, the grooves even in the crystalline rocks attaining a width of 3 to 5 feet (·9 to 1·5 m.) and a depth of 1 to 5 feet (·3 to 1·5 m.). The striations and grooves are not confined to the flat surfaces, but occur also on the sloping and vertical ones, in some instances the rocks being actually undercut.

These features, and curved and spreading striations, indicate the remarkable "plasticity" of ice under great pressure. The smaller ledges have been worn into roches moutonnées, and although their lea ends are usually broad and craggy, they are in places smoothly polished and striated. The abrasion has been greatest on the soft rocks, and has left rounded ledges of the hard rocks in relief. Many of the rounded points of the shore line are of this nature. The general direction of movement seems to have been slightly west of south. Locally, owing to the influence of topography, the movement appears to have varied considerably from this direction. The influence of the topography varied at successive stages of glaciation, and as a result cross striations were produced. The direction of the grooves varies only from 10 to 20 degrees from south, but that of the striations, which frequently cross the grooves and are later, varies at least from S. 50° E. to S. 35° W. This fact indicates that the minor topographic features had little effect on the glacial movement until the stage of glacial retreat. The only superficial deposit formed during this period of glaciation is the Admiralty till. It was doubtless more extensive than appears at present, and probably furnished a large part of the material of the inter-glacial deposits and, as mentioned, may occur on the upland mingled with the Vashon drift. It was deposited directly by ice, some of it being clearly a ground moraine, but part of it was apparently deposited in water, probably below sea-level.

On the retreat of the Admiralty glaciers the land stood at least 200 feet (60 m.) lower than at present, since marine fossils occur in the inter-glacial deposits up to that elevation. Presumably the drowned pre-Glacial lowland formed estuaries, and in these estuaries, under conditions of comparative quiet and of moderate temperature, the Maywood clays were deposited. The glaciers had not, however, completely disappeared from the region as the irregularly distributed pebbles and large erratic glacial boulders in the clays testify, since they were doubtless dropped from floating ice. During the later stages of the inter-glacial epoch, when the Cordova sands and gravels were being deposited, either shallower water prevailed or else the rivers and streams issuing from the ice front, perhaps advancing at this time, were more heavily laden with coarser detritus.

During the epoch of Vashon glaciation, the Vashon drift was deposited largely by ice alone, but doubtless in part by water. The Vashon galciers were smaller than those of the Admiralty period, for the Vashon drift rests directly upon the hard glaciated rocks in the upland regions only, since the piedmont glaciers, which over-rode the lowland, were unable to remove the covering of inter-glacial deposits, eroding merely portions of these deposits.

To judge from the absence of moraines of Vashon drift, the retreat of the Vashon glaciers must have been fairly rapid. Nevertheless the Colwood delta was doubtless formed at the front of one or more of the retreating glaciers, presumably in salt water. This delta has since been uplifted about 250 feet (80 m.).

Particular Descriptions.

Excursion C 1. (First Day).

From the Empress hotel the route of the excursion lies along the shore south of Victoria to Oak bay and across the cities of Oak Bay and Victoria, stops being made at various points of interest.

Locality 1.—Contact shatter-breccia of Wark gabbro-diorite gneiss and Saanich granodiorite, cut by complex of diorite porphyrite dykes. Minor faulting. Glacial scouring, roches moutonnées, deep grooves, and striations. General view of contraposed shore-line.

Locality 2.—Good view to the east of an irregular rocky (contraposed) shore line. Hard rocks overlain by retrograded Vashon drift and Maywood clays.

Locality 3.—Contact complex and shatter breccia of Vancouver meta-andesite, Wark gabbro-diorite gneiss, and Saanich granodiorite. Aplitic apophyses with quartz segregations and quartz veinlets. Hybridism. Breccia foliated and slightly faulted. Glacial grooving and striation. East to Clover point, submaturely retrograded portion of shore line. Clover point, hard rock headland showing beginning of contraposition.

Locality 4.—Between 3 and 4 pre-Glacial lowland covered by Maywood clays with a thin mantle of Vashon drift and frequent outcrops of Vancouver meta-volcanics. To the south Gonzales hill, altitude 215 feet (65 m.) a monadnock surmounting the lowland.

Vancouver meta–volcanics, foliated flow–breccia. Roches moutonnées, grooving, and crossed striations.

Locality 5—Between 4 and 5 pre-Glacial lowland of Maywood clays with thin mantle of Vashon drift and numerous outcrops of Vancouver meta–andesites. Foliated, contact metamorphosed Vancouver volcanics, cut by a great number of quartz-feldspar masses and irregular apophyses of quartz-diorite.

Locality 6.—Contact complex of Vancouver meta–andesites and Wark and Colquitz gneisses. Hybridism and primary gneisses.

Locality 7—Between 6 and 7 pre-Glacial lowland with small glaciated monadnocks and ledges chiefly of Wark gabbro-diorite gneiss.

Road-cut in drift, showing relations of Admiralty till, Maywood clays, and Vashon till.

Excursion C 1 (Second Day).

From the Empress hotel the route of the excursion lies north and west of Victoria to a number of points of geolo-gical interest.

Locality 8—Vashon drift, unconformably overlying Cordova sands and gravels, which overlie Maywood clays. Latter not exposed here. Sand and gravel pits, from which material is obtained for mortar, concrete, filling, etc.

Locality 9—Between 8 and 9, pre-Glacial lowland largely covered by Maywood clays, few outcrops of Wark and Colquitz gneisses.

Mt. Tolmie, altitude 383 feet (95 m.), a monadnock of Wark gabbro-diorite gneiss, protected the Cordova sands and gravels from erosion during Vashon glaciation. Section of drift and Cordova sands and gravels. Sand and gravel bank.

Locality 10—Between 9 and 10 pre-Glacial lowland with numerous small monadnocks and large ledges, chiefly of Wark gneiss.

View of wooded "train" of Cordova sands and gravels in lea of large monadnock, Mt. Douglas or Cedar hill, altitude 725 feet (220 m.).

Locality 11—From 10 along wooded "train" of Cordova sands and gravels to top of Mt. Douglas.

Wark gabbro-diorite gneiss, cut by aplite veins. General view of pre-Glacial lowland, uplifted Tretiary peneplain—

the Vancouver Island upland—,Pacific Coast and Juan de Fuca downfolds, and Coast range and Olympic mountains.

Locality 12—From 11 to 12 across pre-Glacial lowland with numerous ledges of Wark and Colquitz gneisses.

Sharp contact of Wark and Colquitz gneisses. Coarse grained, recrystallized phases, and fine grained segregations of Wark gabbro-diorite. Pegmatite dykes. Foliation. Glacial grooves, striations, and roche moutonnée.

Locality 13—From 12 south to Victoria and across Esquimalt peninsula, pre-Glacial lowland with numerous small monadnocks or ledges of the crystalline rocks, but largely covered by Maywood clays with a thin mantle of Vashon drift in places. To east and west of Esquimalt peninsula the drowned submaturely glaciated valleys of Victoria and Esquimalt harbours. To northwest, upland, formed by late mature dissection of uplifted Tertiary peneplain, transitional in character to the Vancouver Island upland.

Quarry in Sutton limestone. Limestone used for flux by Tyee Copper Company's smelter at Ladysmith. Dyke of sheared basalt porphyrite of Vancouver volcanics.

Locality 14—Sutton limestone lens in contact with Saanich granodiorite. Apophyses of granodiorite and irregular dykes of basalt porphyrite. In places limestone contact metamorphosed, silicified, and converted into garnet-diopside-epidote rock, with small body of magnetite and chalcopyrite. Limestone quarried for manufacture of lime.

Locality 15—Between 14 and 15, Colwood delta.

Section of Colwood delta showing top-set and fore-set beds. Hydraulicking of deposit for sand and gravel, used for concrete, filling, etc.

Locality 16—From 15 across Colwood delta and Albert head. Headland composed of Metchosin volcanics.

Metchosin basalts. Tuffs and agglomerates, some with water worn fragments, "concretions," and "bombs." Vesicular and amygdaloidal basalts. Diabase dykes and pipes. Denuded volcano (?). Columnar jointing. Fossiliferous tuffs (upper Eocene gastropods). Secondary minerals, calcite, quartz, and zeolites. Glacial grooves, striations, and roches moutonnées.

Locality 17—Metchosin basalts, columnar jointing and pillow structure.

Locality 18—From 17 back on to Colwood delta.

Kettle or ice block holes near inner border of delta. Large ledges of Metchosin basalts to west.

Locality 19—From 18 across terraced Colwood delta.

Iron Mask mineral claim on south slope of Mill hill, altitude 631 feet (195m). Contact metamorphosed Vancouver andesites, amphibolites, which have been sheared, solicified, and mineralized, cut by quartz veinlets, and replaced by garnet-diopside-epidote rock, with magnetite, pyrrhotite, pyrite, and chalcopyrite.

Locality 20—To the west Sutton limestone quarried for the manufacture of lime. Lime hydrated and used in the manufacture of sand-lime brick. Sand from Colwood sands and gravels.

Locality 21—Unfoliated shatter breccia of Wark and Colquitz gneisses. Hybridism and development of hornblendite.

Locality 22—Banded Colquitz quartz diorite gneiss, primary gneiss. Small pegmatite dykes, small faults and contortions.

Locality 23—From 22 over pre-Glacial lowland. Numerous ledges of Wark gneiss and small monadnock, Knocken hill, to north, altitude 260 feet (79 m.), and drowned glaciated valley, Portage inlet, to south.

Pot-hole in Wark gabbro-diorite gneiss, formed by glacial stream descending through a crevasse or by inter-glacial stream. Wark gneiss cut by apophyses of Colquitz quartz diorite.

Locality 24—From 23 over pre-Glacial lowland, largely covered by Maywood clays with thin mantle of Vashon drift in places, and a few outcrops of Wark gneiss.

Maywood clays. Clays used for the manufacture of common brick and tile. Marine fossils.

Excursion C 2 (Section I.)

From the Empress Hotel the excursion proceeds west across the Esquimalt peninsula, which is a portion of the pre-Glacial lowland, with numerous small monadnocks or ledges of the crystalline rocks, largely covered by Maywood clays, with a thin mantle of Vashon drift in places. To the east and west of Esquimalt peninsula the drowned submaturely glaciated valleys of Victoria and Esquimalt harbours. To northwest, upland formed by

late mature dissection of uplifted Tertiary peneplain, transitional in character to the Vancouver Island upland.

Locality 1—Quarry in Sutton limestone. Limestone used for flux by Tyee Copper Company's smelter at Ladysmith. Dyke of sheared basalt prophyrite of Vancouver volcanics.

Locality 2—Sutton limestone lens in contact with Saanich granodiorite. Apophyses of granodiorite and irregular dykes of basalt porphyrite. In places limestone contact metamorphosed, silicified, and converted into garnet-diopside-epidote rock, with small body of magnetite and chalcopyrite. Limestone quarried for manufacture of lime.

To the southwest, Sutton limestone quarried for the manufacture of lime. Lime hydrated and used in the manufacture of sand-lime brick. Sand from Colwood sands and gravels.

Locality 3—From 2 across Colwood delta.

Section of Colwood delta showing top-set and fore-set beds. Hydraulicking of deposit for sand and gravels, used for concrete, filling, etc.

Locality 4—From 3 across Colwood delta and Albert head. Headland of Metchosin volcanics.

Metchosin basalts. Tuffs and agglomerates, some with water worn fragments, "concretions", and "bombs". Vesicular and amygdaloidal basalts. Diabase dykes and pipes. Denuded volcano (?). Columnar jointing. Fossiliferous tuffs (upper Eocene gastropods). Secondary minerals, calcite, quartz, and zeolites. Glacial grooves, striations, and roches moutonnées.

Locality 5—Metchosin basalts, columnar jointing and pillow structure.

Locality 6—From 5 back on to Colwood delta.

Kettle or ice block holes near inner border of delta. Large ledges of Metchosin basalts to west.

Locality 7—Unfoliated shatter breccia of Wark and Colquitz gneisses. Hybridism and development of hornblendite.

Locality 8—Banded Colquitz quartz diorite gneiss, primary gneiss. Small pegmatite dykes, small faults and contortions.

Locality 9—From 8 over pre-Glacial lowland. Numerous ledges of Wark gneiss and small monadnock, Knockan hill to north, altitude 260 ft. (79 m.), and drowned glaciated valley, Portage inlet to south.

Pot hole in Wark gabbro-diorite gneiss, formed by glacial stream descending through a crevasse, or by interglacial stream. Wark gneiss cut by apophyses of Colquitz quartz diorite.

Locality 10—From 9 over pre-Glacial lowland, largely covered by Maywood clays with thin mantle of Vashon drift in places and a few outcrops of Wark gneiss.

Maywood clays. Clays used for the manufacture of common brick and tile. Marine fossils.

Excursion C 2, (Sections I and II).

Leaving the Empress hotel the entire excursion proceeds along the shore south of Victoria to Oak bay, stopping at various points of interest, and then returns to Victoria, via Mt. Tolmie.

Locality 11—Contact shatter breccia of Wark gabbro-diorite gneiss and Saanich granodiorite, cut by complex of diorite porphyrite dykes. Minor faulting. Glacial scouring, producing roches moutonnées, deep grooves, and striations. General view of contraposed shoreline.

Locality 12—Good view to the east of an irregular rocky, contraposed shore line. Hard rocks overlain by retrograded Vashon drift and Maywood clays.

Locality 13—Contact complex and shatter breccia of Vancouver meta-andesite, Wark gabbro-diorite gneiss, and Saanich granodiorite. Aplitic apophyses with quartz segregations and quartz veinlets. Hybridiom.

Breccia foliated and slightly faulted Glacial grooving and striation. East to Clover point, submaturely retrograded portion of shore line. Clover point, a hard rock headland, showing beginning of contraposition.

Locality 14—Between 13 and 14 pre-Glacial lowland covered by Maywood clays with a thin mantle of Vashon drift and frequent outcrops of Vancouver meta-volcanics. To the south Gonzales hill, altitude 215 feet (65 m.), a monanock surmounting the lowland.

Vancouver meta-volcanics, foliated flow-breccia. Roches moutonnées, grooving, and crossed striations.

Locality 15—Between 14 and 15 pre-Glacial lowland of Maywood clays with thin mantle of Vashon drift and numerous outcrops of Vancouver meta-andesites. Foliated, contact metamorphosed Vancouver volcanics, cut by a

great number of quartz-feldspar masses and irregular apophyses of quartz diorite.

Locality 16—Contact complex of Vancouver meta-andesites and Wark and Colquitz gneisses. Hybridism and primary gneisses.

Locality 17—Between 16 and 17 across pre-Glacial lowland largely covered by Maywood clays, few outcrops of Wark and Colquitz gneisses.

Mt. Tolmie, altitude 383 feet (95 m.), a monadnock of Wark gabbro-diorite gneiss cut by pegmatite and aplite dykes and quartz veins. Grooving and striations. Cordova sands and gravels in lea of monadnock protected from erosion during Vashon glaciation. Section of Vashon drift and Cordova sands and gravels. Sand and gravel bank. General view of pre-Glacial lowland and uplifted Tertiary peneplain—the Vancouver Island upland—, Pacific Coast and Juan de Fuca downfolds, and Coast range and Olympic mountains.

Locality 18—From 17 to 18 pre-Glacial lowland largely covered by Maywood clays, few outcrops of Wark and Colquitz gneisses.

Vashon drift, unconformably overlying Cordova sands and gravels, which overlie Maywood clays, Latter not exposed here. Sand and gravel pits. Sand and gravel used for mortar, concrete filling, etc.

ANNOTATED GUIDE.

(Vancouver to Nanaimo.)

Excursion C 2, Section II.

Miles and Kilometres.

0 m.
0 km.

Vancouver—Leaving Vancouver the steamer sails westward through the narrow pass called the First Narrows, at the entrance of Vancouver harbour, into the Strait of Georgia. To the north are the lower mountains of the Coast range, composed largely of granitic rocks, and to the south is the low area underlain by the relatively unresistent Eocene sediments, consisting largely of sandstones and conglomerates, only moderately disturbed, and well exposed in

Miles and Kilometres.

the shore cliffs [**9**]. The Eocene sediments are almost entirely covered with the thick deposit of clay, sand, and gravel comprising the Fraser River delta, built largely in post-Glacial times and recently uplifted some 400 feet (120m.) and cliffed during the present marine cycle, so that the old delta appears conspicuously to the south as the steamer sails west across the open waters of the Strait of Georgia. The present delta of the Fraser forms an extensive lowland, only a few feet above sea level, that extends south from the older, uplifted delta.

To the west is Vancouver island. In clear weather a good general view of it may be had. The dark mass of the Vancouver range, composed largely of metamorphic and crystalline rocks, steeply surmounts the coast lowland which is underlain by the less resistant sediments of the Nanaimo series. Most of the summits are rounded or ridge-like, but a few snow capped and serrated peaks are seen crowning the whole.

After crossing the Strait of Georgia, the steamer enters Fairway channel between Entrance and Gabriola islands to the south and Snake island to the northwest. These islands are built of the upper formations of the Nanaimo series, which are here involved in a large syncline pitching to the north. Turning south, the steamer sails along a drowned valley largely underlain by shales, between sandstone islands, Gabriola island to the east and Newcastle and Protection islands to the west. Rounding the southern point of Protection island, on which is seen the surface workings of the Protection shaft of the Western Fuel Company's collieries, the steamer enters Nanaimo harbour. Directly to the west is the city of Nanaimo,

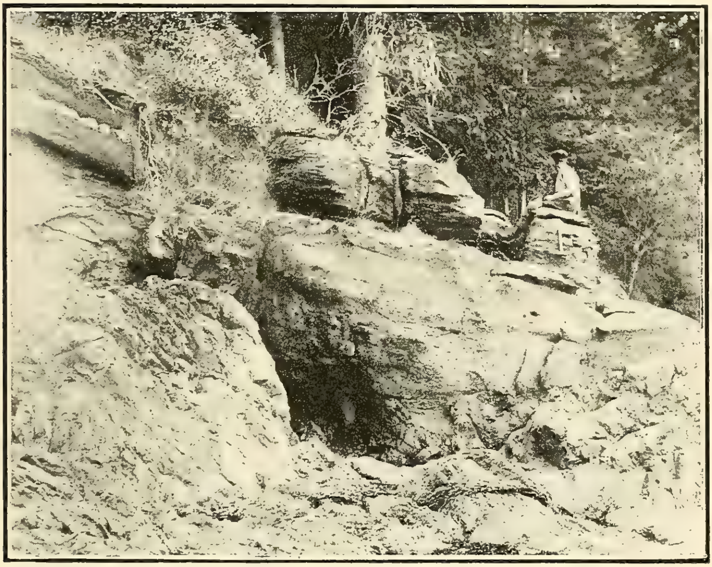
41 m.
66 km.

Nanaimo—built on the coastal lowland of sedimentary rocks of the Nanaimo series. In the background is Mt. Benson, 3,300 feet high (1,000 m.) composed of Vancouver volcanics, around which the Nanaino series forms a narrow fringe.

GEOLOGY OF THE REGION AROUND NANAIMO.

PHYSIOGRAPHY.

The region around Nanaimo (**5**) is a part of the east coast lowland of Vancouver island. Since the sedimentary rocks underlying the lowland are varyingly resistant, as well as moderately disturbed, their predominating strike



Basal unconformity, shore west of Neck point, Wellington district, showing the irregularities of the surface on which the Nanaimo series was deposited.

being northwest and their dip northeast, the lowland has considerable relief, extensive valleys having been developed in belts of soft rocks, between ridges composed of more resistant beds. The hard rock ridges are of the cuesta type with very steep, in places nearly vertical, front slopes and gentle dip or back slopes. Tongues of the crystalline rocks extend eastward from the upland to the west, and form low eastward trending ridges increasing in elevation to the westward. One of the ridges in the northern part of the region forms the northern boundary of the sedimentary rock basin, and another west of Nanaimo is

the flank of Mt. Benson. It appears as if the eastern part of the Nanaimo basin had been depressed below sea level, and the valleys drowned to form the long, wide channels, passes, and harbours of the region. The hard rock ridges remain above sea level as long points and islands. During the Glacial period the region was glaciated, and the rock surfaces were smoothed, and the valleys deepened. Upon the retreat of the glaciers the region apparently stood a few hundred feet lower than at present, for up to an elevation of 400 feet (120 m) occur stratified sands and gravels, in part of marine or estuarine origin. A recent uplift has brought the land into its present position, and initiated the present erosion cycle, during which the revived streams have terraced the superficial deposits, and have cut narrow canyons in the indurated rocks, while the superficial deposits fronting on the coast have been retrograded to form cliffs up to 100 feet (30 m.) in height.

General geology.

The crystalline rocks, upon which the coal bearing sediments of the Nanaimo series rest unconformably, are the Vancouver meta-andesites. The volcanic rocks were greatly deformed, metamorphosed and intruded by granitic rocks, probably in late Jurassic time. The granitic rocks were subsequently exposed, since boulders and pebbles of them occur in the sediments of the Nanaimo series. However, the crystalline rocks were apparently not worn down to a lowland, because the surface upon which the sedimentary rocks were deposited is seen to be one of considerable relief. Small irregularities are directly observable in exposed unconformities, and the contacts of the Nanaimo series with the underlying rocks, where not disturbed by intense folding and faulting, follow very closely the contours of present elevations, which must have been elevations at the time of deposition also, unless far more irregular and complex folding than is elsewhere observed is supposed.

The Nanaimo series, as shown by its fauna, is partly of marine origin, probably estuarine, since it was deposited

on a surface of considerable relief, and under varying conditions, as shown by the rapid lateral and vertical gradation of the sediments. The series also contains land plants and coal, probably of fresh water accumulation. Hence conditions of fresh or at least brackish water, that is, terrestrial conditions, alternated with marine conditions. The upper part of the Nanaimo series, however, contains few or no marine organisms, the only fossils being a few obscure plants. It is possible therefore, that the alternating conditions recorded in the lower part of the Nanaimo formation were finally replaced entirely by terrestrial conditions. The lithological character of the sediments—the sandstone being composed of angular to sub-angular fragments and of a large percentage of easily decomposed minerals such as feldspar—indicates a very rapid accumulation and deposition in relatively small basins, where the detritus was not subject to severe wave action. The sedimentation began in Upper Cretaceous time, at a stage corresponding with the Chico, or the Pierre, and it appears as if the sediments were first deposited in a marine basin, between the mainland and Vancouver island, which basin was probably one of deformation, depressed at least as early as the upper Jurassic. During the deposition, the sedimentation trangressed inland, at first filling up the irrgularities of the pre-Upper Cretaceous erosion, and then possibly covering even the higher residual elevations. The total thickness of the Nanaimo series was near 10,000 feet (3,000 m.) toward the close of its deposition, at which time it extended far inland over the denuded crystalline rocks covering the greater part of the island, or was perhaps restricted to large depressions.

The conditions of deposition in the northwestern part of the Nanaimo basin, where the coal deposits occur, appear to have been more uniform than these which existed elsewhere, for there the series may be subdivided solely on a lithological basis into various formations each with its more or less peculiar characteristics. The formations are enumerated and their thickness and general lithological character given in the following table:—

Formation	Description	Thickness: Minimum, Feet	Minimum, Metres	Maximum, Feet	Maximum, Metres	Average, Feet	Average, Metres
Gabriola formation	Chiefly sandstones	1,400	426	1,400	426	1,400	426
Northumberland formation	Conglomerates, sandstones and shales	1,100	335	1,200	365	1,150	350
De Courcy formation	Chiefly sandstones	800	243	1,400	426	850	259
Cedar district formation	Chiefly shales	700	213	1,000	304	750	228
Protection formation	Chiefly sandstones	600	182	750	228	650	198
Newcastle formation (Douglas coal seam) (Newcastle coal seam)	Fine conglomerates and sandy shales, contains Douglas seam	150	45	400	122	200	61
Cranberry formation	Flaggy and shaly sandstones and sandy shales, gritty sandstones and fine conglomerates	150	45	500	152	250	76
Extension formation (Wellington coal seam)	Chiefly conglomerates, also shales, and sandstone horizons and small coal seams	700	213	1,500	457	800	243
Eastwellington formation	Sandstone	35	10	50	15	35	10
Haslam formation (marine shales) (Departure Bay calcarenites)	Chiefly shales	500	152	800	243	600	182
Benson formation	Basal conglomerate	0	0	400	122	100	30
Total		6,125		9,400		6,785	

In general the conglomerates are composed chiefly of quartz and quartzose rocks; the sandstones chiefly of granitic detritus, quartz and feldspar; and the shales chiefly of volcanic detritus, being grayish green in color. From the mere statement of these facts, which constitute a rather peculiar feature of the lithology, a simple yet fairly plausible explanation suggests itself. Of all the underlying rocks whose detritus composes the sediments, the volcanic rocks alone were chemically disintegrated, and their detritus, being very fine grained, was deposited as mud which now forms the shales. The granitic rocks were mechanically disintegrated, and broken down into a coarse feldspathic sand, furnishing the material for the sandstones. The quartz veins and the quartzose rocks, however, were broken down only into a coarse rubble to form the material for the conglomerates.

A peculiar feature of the shale horizons of the upper part of the Nanaimo series, especially of those characterized by a large number of small sandstone interbeds, is the occurrence of numerous sandstone dykes. These cut the shales at all angles to the bedding. They are fairly regular, although branching and offset by faults. The larger, 3 to 4 feet (·9 to 1·2 m.) thick, may be traced for at least 100 feet (30 m.). Although they cut the shales sharply, apparently along joint planes, the shales are frequently bent or slightly contorted next to the dykes. On the shores, where the dykes are best exposed, on account of their greater resistance to wave erosion, they stand above the shales, forming low walls, the highest wall noted being three feet (9 m.).

As a rule the dykes are finer grained than the sandstone interbeds, and the cementing material is more calcareous but in general the two are of similar material. Indeed, in many instances, dykes protrude from the sandstone interbeds, and there are off-shoots from the dykes conformable with the bedding of the shales, that simulate the appearance of sandstone interbeds, but are recognized as off-shoots by occurring usually on one side of the dyke only. There are also other smaller and more irregular off-shoots into the shales, resembling small apophyses from an igneous dyke.

From their occurrence and close resemblance to other intrusive sandstone dykes, their origin is in little question. They appear to have been formed by the injection of soft

sands which were forced usually upward along joint planes in the shale, the injection being similar to that of an igneous dyke. After the injection the sands were firmly cemented by calcium carbonate, precipitated from water circulating through the relatively coarse grained dyke. One important conclusion to be drawn from their occurrence is that movement must have taken place while at least the upper sandstones of the Nanaimo series were in a soft and plastic condition.

Another feature indicates that movement took place while the sediments of the upper part of the series were in a plastic condition. Even in the coarser, most massive beds, such as thick bedded conglomerates, sudden folds or sharp rolls occur, although the beds may be otherwise only moderately disturbed. These rolls, which are really more of the nature of small displacements or faults, are so pronounced that a bed which has a moderate dip in one direction may turn down at right angles, so that the dip of the down-turned portion is vertical and its strike is at right angles to the strike of the bed as a whole. The largest of these sharp rolls, exposed on the west shore near the northern end of Newcastle island, occurs in a coarse grained, thick-bedded conglomerate, and the width of the down-turned portion is about 150 feet (45 m.). In spite of the magnitude and abruptness of the displacement, there is not the slightest indication of extra jointing, shearing, or slickensiding. Instead the fold has occurred as if the conglomerate were as plastic as wet clay. Hence unless we hypothecate more intense folding than is observed and a much thicker cover, which would induce greater pressure, this type of fold can be explained only by the supposition, that the conglomerates and other sediments which have suffered in the same way, were soft and plastic when the folding took place.

The Nanaimo series was subjected to strong orogenic movement also, presumably during the post-Eocene deformation, the deforming forces apparently having their origin to the northeast, probably below the basin between Vancouver island and the mainland. The series was deformed into broad open folds, complicated by small closed folds and reversed faults, the latter largely restricted to the western boundary of the basin. The axes of folding have a

general northwest-southeast strike, and the prevailing dip is to the northeast. At the northern rim of the basin in the vicinity of Departure bay, the general strike turns from northeast to east, while the dip is to the southeast and south. The largest fold, with the exception of the major fold which outlines the basin, occurs on Gabriola island. It is a syncline, which is divided into two parts by a transverse anticlinal roll at the northern end of the island.

A large portion of the region about Nanaimo is covered by superficial deposits of various kinds, which are, however, almost entirely referable to the Glacial period. This period was characterized by two epochs of glacial occupation, the Admiralty and the Vashon, separated by an inter-glacial epoch, the Puyallup. Little or nothing remains of the glacial till, which must have mantled a large part of the area on the retreat of the earlier and larger Admiralty glaciers. During the Puyallup inter-glacial epoch, a large part of the lowland must have been covered by stratified sands and clays, partly, if not entirely, of marine origin. These inter-glacial deposits were largely eroded during the Vashon glaciation, but now occur mantled by a more or less persistant covering of Vashon drift, to the northwest of Nanaimo and in the broad low area adjoining the lower part of the Nanaimo river, to the south of Nanaimo. On the retreat of the Vashon glaciers, large delta deposits, composed chiefly of sand and gravel, were built at the mouths of the large valleys, which extend eastward from the Vancouver Island upland, and were at that time presumably occupied by retreating valley glaciers. The deposits have a maximum elevation of about 400 feet (120 m.). The islands are not covered by these deposits but merely by debris of the immediately underlying rocks mixed with more or less glacial till and sometimes overlying or closely associated with stratified sand and clay of the inter-glacial deposits. It thus appears as if during the deposition of the delta deposits the islands were still covered by the piedmont Strait of Georgia glacier. It may be that the deltas were deposited in lakes dammed by the Strait of Georgia glacier, but, since it is positively known by the occurrence of marine fossils in the vicinity (on Texada island and near Vancouver) at elevations near 400 feet (120 m.) that a recent uplift of about 400 feet

(120 m.) has occurred, it is more probable that the deltas were deposited in the salt water. As already mentioned, since the uplift the delta deposits have been terraced and retrograded.

The other superficial deposits consist of recent swamp, valley, delta, and beach alluvium.

Geology of the Coal Deposits.

There are at present three productive coal seams in the Nanaimo district lying in the following succession from the bottom upwards: the Wellington; the Newcastle, sometimes called the lower Douglas; and the Douglas. The lowest seam, the Wellington, occurs about 700 feet (210 m.) above the base of the Nanaimo series, overlying 600 feet (180 m.) of marine sandy shale, the Haslam formation. The Newcastle and Douglas seams, are only from 25 to 100 feet (8 to 30 m.) apart, and overlie the Wellington seam by about 1,000 feet (300 m.), separated from it chiefly by a thick bedded conglomerate, the Extension formation. A fourth and small seam, called the little Wellington, locally overlies the Wellington at a distance of 20 to 50 feet (6 to 15 m.). It has been mined in a small way.

The coals of the various seams are as a whole much alike, and furnish a bituminous coal of fair grade. The amount of fixed carbon in the best quality ranges from 45 to 60 per cent, and the ash from 5 to 10 per cent. The following proximate and ultimate analyses were made by F. G. Wait of the Department of Mines, from samples collected by the writer.

ANALYSES.

Proximate.	1.	2.	3.
Analysis by fast coking.			
Water	1·65	1·16	1·54
Vol. combust	43·25	40·47	33·30
Fixed carbon	45·52	50·04	56·23
Ash	9·24	7·80	8·44
Sulphur	1·24	0·53	0·49
	100·	100·	100·
Coke	55·38	58·11	64·91
Character of coke	firm, coherent.	firm, coherent.	firm, coherent.
Fuel ratio	1·07	1·23	1·65
Split volatile ratio	2·92	3·29	4·00

Ultimate.	1.	2.	3.
Carbon	72·80	75·53	74·46
Hydrogen	5·17	5·13	5·42
Nitrogen	0·88	1·19	1·37
Oxygen	10·67	9·82	9·82
Sulphur	1·24	0·53	0·49
Ash	9·24	7·80	8·44
	100·	100·	100·

No. 1. Coal from the Wellington seam.
No. 2. Coal from the Wellington seam.
No. 3. Coal from the Douglas seam.

The most striking feature of the seams is their great variability in thickness and quality. The thickness varies from nothing to over 30 feet (10 m.), sometimes within a lateral distance of less than 100 feet (30 m.). This variation is caused by irregularities in either the roof or

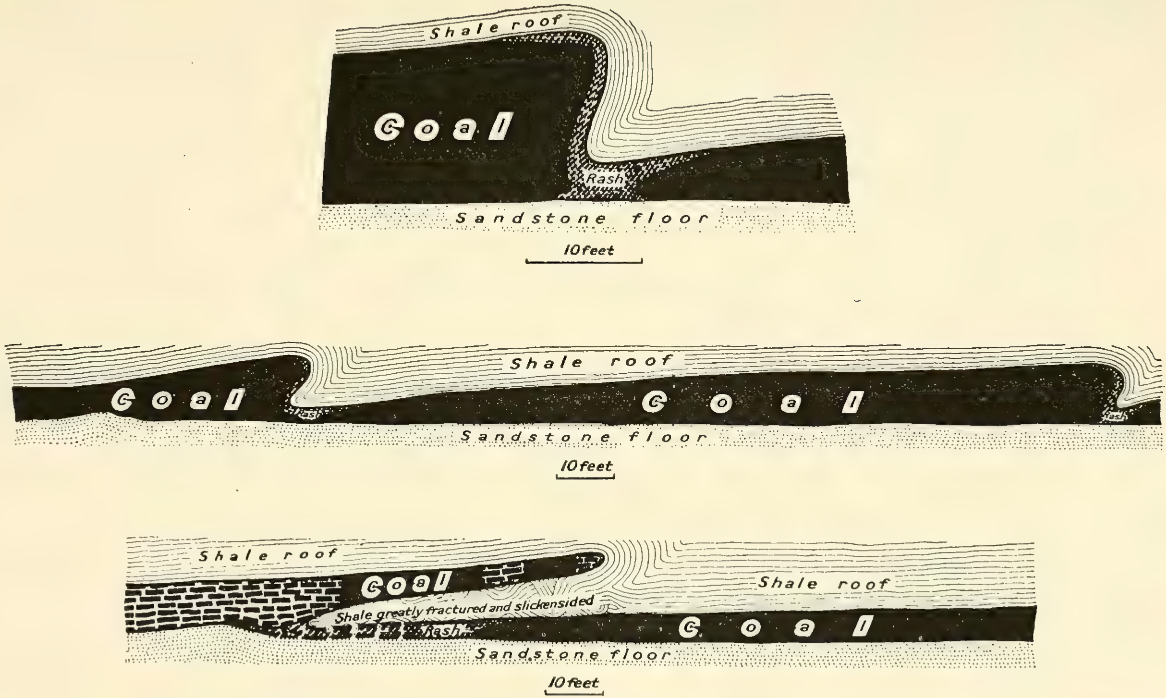
floor, and occasionally in both. In quality the seams vary from where they are entirely composed of clean, bright coal, with about 5 per cent ash, to where they are entirely composed of a dirty slickensided coal, locally called "rash," with over 50 per cent ash. The following is a proximate analysis of the rash from the Wellington seam.

Proximate Analysis by Fast Coking.

Water	1·59
Vol. combust	24·15
Fixed carbon	19·29
Ash	54·97
Sulphur	undet.
	100·

The Wellington seam rests on a firm sandstone floor, which is fairly regular although a few sharp rolls do occur in it. The roof, however, varies greatly in character from sandy shale to conglomerate, with many irregularities, especially in the sandy shale. The average thickness of the seam is from 4 to 7 feet (1 to 2 m.), but it occasionally pinches to virtually nothing, and then suddenly thickens to 10 or 12 feet (3 or 4 m.). The floor may be nearly smooth, but the roof in passing from the thin to the thick portion of the seam rolls upward sharply and often irregularly. Occasionally the roof is overturned forming in one instance an overlap in the seam of at least 25 feet (8 m.). These sharp rolls are locally called "faults." Invariably at the thin places or "pinches" the coal is dirty and slickensided, while in the thick places or "swells" it is clean, black in colour with a sub-brilliant lustre, and broken only by a few irregular joints. Rash is usually found near the top and bottom of the swells and rarely in thin partings near the centre. Even in the swells some bone is present as small lenses seldom more than a quarter of an inch thick. In some instances the coal is clean and unfractured against the upturned roof, but more commonly it is somewhat slickensided and even contorted. The roof at the rolls is always contorted and slickensided.

The strike of the rolls corresponds with the strike of the measures, that is, northwest to west, and the pinches occur in the northeast and north side of the rolls with the corresponding swells on the opposite side. Where the



Sections of the Wellington seam, showing rolls and overlaps. Where represented as broken, seam inferred.

seam is overlapped, the overlap is to the northeast or north.

These features are illustrated by the accompanying sections which are drawn to scale.

It appears from the evidence given above as if the variation was due in large part to a folding which affected the coal seams when the clean coal was in a fairly plastic condition. This conclusion is especially well substantiated in another part of the Wellington seam, where it is composed of several sub-seams separated by dirty slickensided coal or rash. During the deposition of the seam, conditions in which fairly clean carbonaceous matter was deposited must have alternated with those during which the carbonaceous matter was deposited with a large amount of silt. When the seam was folded, the clean coal was apparently forced away from the tight bends, where the folding caused an increase in the vertical pressure, and left the seam at these places composed almost entirely of rash. The clean coal flowed to where there was a corresponding relief of vertical pressure forming a swell where the seam, except for the rash at the top and bottom, consists chiefly of clean bright coal.

Besides the barren places or wants due to folding subsequent to the deposition of the seam, there are large wants due solely to silting, for in some instances the silting must have persisted throughout the period of coal formation. Also large and persistent partings of shale occur between the sub-seams.

Both types of variation occur in the Douglas seam. The seam varies from nothing to 30 feet (10 m.) in thickness, and averages about five feet (1·5 m.) although over large areas the average thickness of the mineable coal is between three and four feet (·9 and 1·2 m.). The floor of the Douglas seam is usually a rather weak sandy shale, and the roof, although stronger, is very variable, ranging from a sandy shale to a fine grained conglomerate, the principal type being a shaly sandstone with sandstone layers and lenses of fine grained conglomerate. Unlike the conditions in the Wellington seam the pinches and swells are caused chiefly by irregularities in the floor, the roof being fairly smooth. At the pinches the seam is composed almost entirely of rash, like that of the Wellington seam, although as a rule it is harder. The coal occurring in the swell has a compact texture, but rather dull lustre. It is irregu-

larly broken into large blocks. Near the pinches some of the coal is slickensided and contorted, but where these features are shown the coal contains a higher percentage of ash. The coal seam is displaced also by small faults, although an actual break seldom occurs, the coal having been forced along the plane or zone of dislocation. Rarely the entire seam folds or wrinkles without any appreciable variation in thickness.

The Newcastle seam is more regular than the Wellington or Douglas seams, but is thinner, varying, as far as known, from 20 to 45 inches (0·51 to 1·15 m.) where mined, and contains more numerous and more regular partings. It is also less extensive in area than the other two seams.

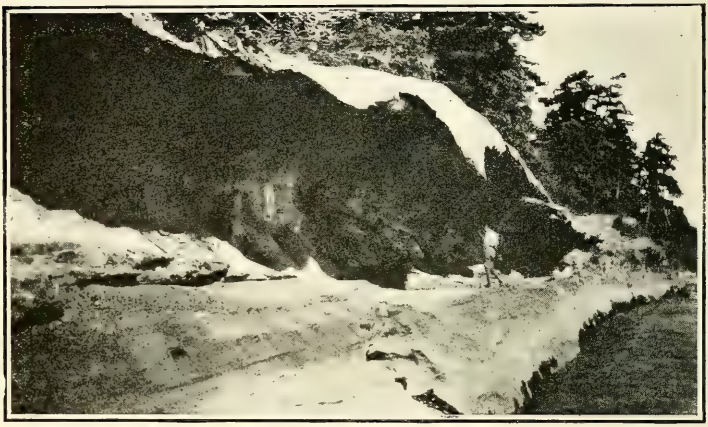
The coal has been the source of a flourishing industry for over 50 years. The Wellington seam has been mined at Wellington, Northfield, East Wellington, Harewood Plains, and Extension, and is at present mined by the Vancouver-Nanaimo Coal Mining Company at East Wellington and by the Canadian Collieries (Dunsmuir) Company near Extension. The Newcastle and Douglas seams, which are usually worked together, have been mined extensively in the vicinity of Nanaimo. The mines here are operated by the Western Fuel Company. There has also been a large production from the Douglas seam south of Nanaimo, notably at Chase River, Southfield, and South Wellington. In these localities the Newcastle seam, although readily located, is of doubtful value. There is only one mine producing at present in this district, the South Wellington mine, operated by the Pacific Coast Coal Mines. Both the Western Fuel Company and the Pacific Coast Coal Mines are sinking new shafts along the lower part of the Nanaimo river to open up the Douglas seam in depth. The present coal production is over 1,000,000 tons per year, and the importance of the Nanaimo district in the coal industry may be more readily comprehended when it is realized that it produces over one third of the entire coal output of British Columbia.

PARTICULAR DESCRIPTION.

From Nanaimo an excursion is made eastward across Nanaimo harbour to Gabriola island. To the south are the wharfs and coal bunkers of the Western Fuel Company.

The inner part of the harbour is underlain by Protection sandstone, exposed to the north on Newcastle and Protection islands. On Protection island, Protection island shaft, cutting the Douglas seam at 588 feet (179 m.) and the Newcastle seam, at 652 feet (199 m.). Outer part of harbour and Nanaimo valley to the south underlain by Cedar District shales.

Jack Point cuesta composed of DeCourcy sandstones, which dip north of east at an angle of 25 degrees.



Galiano (Malaspina) Gallery.

Northumberland channel underlain by lower shale horizon in the Northumberland formation.

West shore of Gabriola island, cuesta of Northumberland sandstones, dipping north of east at an angle of 10 degrees. Honeycomb weathering.

Decanso bay. Upper shale horizon of the Northumberland formations, underlying concretionary Gabriola sandstones Sandstone quarry.

Along shore of cuesta-like ridges of northeastward dipping Gabriola sandstone. Angle of dip averages 15 degrees.

Locality 1—Galiano (Malaspina) Gallery. Gabriola sandstone, weathered by solution and wind.

Tinson point. Highest beds of Nanaimo series in the vicinity of Nanaimo, nearly 5,000 feet (1,500m.) to Douglas seams. Thin bedded Gabriola sandstones dipping north

at an angle of about 5 degrees. Small bays on either side of point formed in a shaly horizon in Gabriola formation.

Lock bay. Northumberland shales dipping northwest at an angle of about 15 degrees below Gabriola sandstone. From Locality 1 across northward pitching syncline. Transverse anticline crosses Gabriola syncline, which to the south pitches southeast.

Locality 2—Northumberland shales dipping southeast at angle from 10 to 15 degrees, overlain by Gabriola sandstones, exposed in cliff, one quarter of a mile back from shore. Shales with sandstone interbeds and sandstone dykes.

Locality 3—Snake island. Honeycomb and "gallery" weathering of concretionary Gabriola sandstone dipping eastward at an angle of 25 degrees.

Locality 4—Islands and headland of Vancouver volcanics to north, evidently a headland of those rocks that projected into the basin in which the Nanaimo series was deposited. Unconformity, showing irregular surface upon which Nanaimo series was deposited, and coarse basal conglomerates (Benson formation) Departure Bay calcarenites.

Locality 5—From 4 across Departure bay, underlain by Haslam, Extension, and Cranberry formations, which have here a minimum thickness. To the west retrogarded inter-glacial deposit. Abrupt downfold in conglomerate and coarse sandstone of the Cranberry formation.

Locality 6—From 5 through Newcastle Island channel, crossing Newcastle and Douglas seams at narrows. Brechin mine of Western Fuel Company to the west, and old slopes on the two seams to the east.

Quarry in Protection sandstone.

Along Newcastle Island channel to Nanaimo, near contact of Newcastle and Protection formations.

East Wellington Mine—Wellington seam reached through an inclined shaft, paralleling an old slope driven on the little Wellington seam. Wellington seam in mine fairly flat, with low dip from 5 to 10 degrees to the northeast, but to the southwest the seam is faulted in a series of steps, and outcrops at the surface to the southwest of the surface plant with a steep dip to the northeast. Sharp rolls or "faults", smooth sandstone floor, but irregular sandy shale roof, in places overturned. Few small rolls in sandstone floor. Faults in southern part of the mine.

(Nanaimo to Victoria).

Miles and Kilometres.	
0 m. 0 km.	**Nanaimo**—Altitude 133 feet (40m.). From Nanaimo the railroad runs south, and for about two miles follows closely the outcrop of the Douglas seam. To the west may be seen one of the recently abandoned slopes on the Newcastle seam. Farther west is the drift covered lowland terminated by the steep slope of Mt. Benson. Farther south near Chase river the outcrop of the coal seams swings to the east, and to the west are the bare back slopes of the cuestas of Extension conglomerate, which dip northeast toward the railroad.
3·3 m. 5·3 km.	**Stark Crossing**—Altitude 80 ft. (24 m.). At Stark Crossing the railroad turns and runs east for three quarters of a mile (1 km.), and then again follows the outcrop of the Douglas seam south by east for two and a half miles (4 km.). Immediately to the west are the ruins of the old Southfield mine, and a half a mile north of South Wellington is one of the mines now operated by the Pacific Coast Coal Mines, the coal being brought to the surface through two slopes on the seam.
5·3 m. 8·5 km.	**South Wellington**—Altitude 124 ft. (37 m.). At South Wellington is the abandoned Alexandria mine. To the east is the steep front slope or cliff of the cuesta formed by the northeastward dipping Protection sandstones, and to the west across the alluvial-filled, submaturely glaciated valley, formed along the outcrop of the Douglas and Newcastle seams, and in which is situated Cranberry lake, is the back slope of a cuesta of conglomerate of the Cranberry formation. To the south the railroad, after crossing the railroad of the Pacific Coast Coal Mines cuts through the lower part of the white weathering Protection sandstone, and for over a mile runs in places along the back slope of the Protection

Miles and Kilometres

sandstone cuesta. Just before crossing the Nanaimo river, a quarter of a mile north of Cassidy Siding, the railroad runs on to the Nanaimo delta, built at the mouth of the upper part of the Nanaimo River valley, during the recession of the Vashon glaciers and terraced by the recently revived river. Along its present course the revived stream has cut a narrow canyon, 80 feet (24 m.) deep, in the Protection sandstone.

Cassidy Siding—Altitude 132 ft. (40 m.). At Cassidy Siding the Protection sandstone cuesta is seen to the west; to the east are the low terraces of the Nanaimo delta, and still farther east is the drift-filled, glaciated valley formed in the Cedar district shales. To the south the railroad crosses two branches of Haslam creek, which here splits into two or three channels while crossing one of the broad terraces of the Nanaimo delta. South of Haslam creek the railroad traverses the Nanaimo delta nearly to Ladysmith.

10·9 m.
17·5 km.
Brenton—Altitude 95 ft. (30 m.). North of Brenton a cuesta of Protection sandstone is seen east of the track. To the southwest beyond the terraced delta is the monadnock, Mt. Hayes, elevation 1,450 feet (442 m.), composed of Saanich granodiorite, and almost entirely surrounded by the Haslam shales, and hence presumably an island during the deposition of the lower members of the Nanaimo series. From Brenton to Ladysmith the railroad is parallel to the Extension railroad of the Canadian Collieries Company, over which the coal from the Extension mines is brought to Ladysmith. To the north of Ladysmith, the railroad cuts through the Protection sandstone, which has here a nearly vertical dip, the base on which the Nanaimo series rests occurring only a mile to the west.

14·1 m.
22·7 km.
Ladysmith—Altitude 83 ft. (25 m.). To the east is Ladysmith harbour, the drowned southern portion of the glaciated valley developed in the Cedar District shales. Beyond the

Miles and Kilometres.

harbour is the Woodley range, a cuesta developed on the northeastward dipping DeCourcey sandstones. At Ladysmith are the copper smelter of the Tyee Copper Company and the wharfs and washer of the Canadian Collieries Company. South of Ladysmith the railroad closely follows the coast, the coast lowland being but one or two miles wide. To the east glimpses are had of the drowned portion of the lowland. To the west the Vancouver Island upland steeply surmounts the lowland and almost directly west of Chemainus, is Mt. Brenton nearly 4,000 feet (1,200 m.) high.

21·3 m. 33·8 km. **Chemainus**—Altitude 109 ft. (33 m.). South of Chemainus the lowland widens again to four miles (6·4 km.), and is drained by the Chemainus river. It is largely drift covered and wooded, and only a few outcrops are seen.

25·7 m. 41·4 km. **Westholme**—Altitude 29 ft. (9 m.). South of Westholme the railroad enters a wide flat-bottomed valley, the northern part of which between Mt. Richards, 1,100 feet (340 m.) high on the east and Mt. Sicker, 2,400 feet (730 m.) on the west, is underlain by the Nanaimo sediments. The Nanaimo sediments almost surround the northern part of Mt. Richards, having been deposited around it while the mountain itself remained above sea-level as an island or peninsula. Both Mt. Richards and Mt. Sicker are composed of the more or less mineralized schistose and intrusive rocks of the Sicker series, a few outcrops of which occur in the southern and narrowest part of the valley. On Mt. Sicker occurred the Tyee-Lenora lens of copper ore. The Lenora railroad, extending from the mine to Crofton, and now used as a lumber railroad, is crossed a mile beyond Westholme, and at Tyee the aerial tram of the Tyee Copper Company comes down from Mt. Sicker.

28·1 m. 45·2 km. **Tyee**—Altitude 129 ft. (39 m.). South of Tyee the railroad cuts through some deformed black slaty shales. To the west on Mt. Prevost, 2,643 feet (806 m.) high, these shales

Miles and Kilometres.

are unconformably overlain by conglomerate, apparently of the Nanaimo series, and still farther west in the valley of Chemainus river the shales grade northward into the Sicker schists. They are presumably of Jurassic or Triassic age, but are indistinguishable from the Nanaimo shales which occur to the east below the drift-covered flat extending from the railroad to the shore.

29·9 m. 48·1 km. **Somenos**—Altitude 108 ft. (33 m.). From Somenos to south of Cowichan the railroad crosses the large, maturely glaciated, subsequent Cowichan valley, underlain by a closely folded syncline of Nanaimo sediments, largely sandstones and shales. The valley is almost 50 miles (80 km.) long, and nearly divides the southern part of Vancouver island. It is glacially deepened, especially in its upper part, where Cowichan lake lies. The Cowichan river flows eastward from the lake, and for the greater part of its course meanders in its flat valley floor, some two to three miles wide, between cut banks 10 to nearly 200 feet (3 to 60 m.) high, of stratified drift of inter-glacial and post-glacial deposition, the river having been revived by the recent uplift. At Somenos is a brick plant using the inter-glacial clays, which cover a large part of the lower portion of the valley.

32·8 m. 52·8 km. **Duncan**—Altitude 50 ft. (15 m.). Between Somenos and Duncan, to the east of the railroad, is Somenos lake, formed in one of the partly drained hollows in the inter-glacial clays. East from Duncan is Mt. Tzuhalem, which is capped by the basal conglomerates of the Nanaimo series resting unconformably on the Sicker schists and porphyrites. The southern slope is a fault line scarp, developed along the fault which has thrown the Sicker series up against the Nanaimo series to the south. Farther to the east is Saltspring island, composed largely of the rocks of the Sicker series. The greater part of the island has an elevation of 1,500 to 1,800 feet (450 to 540 m.) and is a

Miles and Kilometres.

remnant of the uplifted Tertiary peneplain. Its southern slope is a fault line scarp, developed along the eastward continuation of the fault mentioned above.

34·4 m. **Koksilah**—Altitude 28 ft. (9 m.).
55·4 km.

37·0 m. **Cowichan**—Altitude 119 ft. (36 m.).
59·6 km.

38·4 m. **Hillbank**—Altitude 150 ft. (46 m.). North
61·8 km. of Cowichan is a quarry in the Nanaimo sandstones, which are seen to be underlain by shales. The last exposures of the Nanaimo sandstones are seen to the north of Hillbank.

41·3 m. **Cobble Hill**—Altitude 315 ft. (96 m.). To
66·5 km. the west of Cobble Hill station is Cobble hill, 1,100 feet (355 m.) high, which with the exception of the northern slope underlain by Saanich granodiorite, is composed of Vancouver metavolcanics, which form a belt 2 to 20 miles (3 to 30 km.) wide extending to the west coast. Numerous outcrops of the volcanics are seen near the railroad to the south of Strathcona and along the northern shore of Shawnigan lake, although the volcanics are largely covered by Vashon till. Just to the south of Strathcona is a small lentil of Sutton limestone which is intercalated in the Vancouver volcanics.

44·7 m. **Koenig**—Altitude 390 ft (119 m.).
71·4 km.

Strathcona—Altitude 456 ft. (139 m.).

25 Mile Post—Altitude 553 ft. (168 m.). Shawnigan lake has been formed in the glacially deepened portion of one of the mature, transverse, north-south valleys, which dissect the uplifted Tertiary peneplain. From Koenig the railroad climbs rather rapidly up the steep east slope of the Shawnigan Lake valley to the pass east to the next transverse north-south valley.

52·5 m. **Malahat**—Altitude 915 ft. (279 m.).
84·5 km.

55·5 m. **17 Mile Post**—Altitude 733 ft. (223 m.).
89·3 km. Beyond Strathcona and extending over the

Miles and Kilometres.

summit at Malahat nearly to 17 Mile Post, is the Wark gabbro-diorite gneiss, numerous outcrops of which are seen near the track and on the slopes up to the level of the uplifted Tertiary peneplain. Frequent apophyses of the Colquitz quartz diorite gneiss are also seen, in places so numerous as to form a breccia of the two rocks. From the summit the railroad descends along the west slope of the maturely glaciated, transverse, north-south valley, which has been converted into a fiord, called Saanich inlet. The southern or typical fiord portion, along the side of which is the railroad, is called Finlayson arm. To the south of 17 Mile Post for nearly five miles (8 km.) the road traverses an area of schistose volcanic rocks, cut by two intrusive masses of the Colquitz and Wark gneisses. The volcanics are largely fragmental, of the composition of dacites and andesites, and are interbedded with sedimentary material. They are greatly deformed and their dips are nearly vertical. They have been mapped with the Vancouver volcanics but are interbedded with and transitional into the Leech River slates, which lie to the south and which are probably Palæozoic. At 15 and 14 Mile Posts, canyons, called respectively Arbutus and Niagara canyons, are crossed on high bridges. They are the spillways of hanging valleys. South of the schistose volcanics are the Leech River slates, greatly deformed, contorted and cut by quartz veins. At the bend in the railroad west of Goldstream, the Goldstream river is crossed. Here the Leech River slates are covered by stratified coarse gravels, which constitue the top-set beds of the Colwood delta, built during the recession of one of the Vashon glaciers which occupied Goldstream valley. To the north of the bridge the Colwood gravels are seen resting on the blue Vashon till. From the bridge to Goldstream the railroad follows the profound overthrust fault which separates the Palæozoic Leech River slates from the Eocene Metchosin basalts,

Miles and Kilometres.

which lie to the south. The fault is marked by a wide shear zone, with slickensided walls, some of which may be seen in the cuts south of the track.

61·8 m.
99·5 km. **Goldstream**—Alt. 280 ft. (85 m.). From Goldstream to Colwood, the railroad crosses the terraced Colwood delta. To the north of the track is Langford lake in one of the undrained hollows of the delta, possibly an ice-block hole. To the east of Langford lake is a gravel pit, where the coarse, horizontally bedded top-set beds are well exposed, resting on the finer, cross and steeply bedded fore-set beds. The gravel is used for railroad ballast.

64·6 m.
104·0 km. **Colwood**—Altitude 246 ft. (75 m.). To the east of Colwood, the railroad descends from the delta nearly to sea level, cutting through the Vancouver volcanics, Sutton limestone lentils, and small intrusive masses of Wark gabbro-diorite gneiss and Colquitz quartz-diorite gneiss. To the north of the track, a mile beyond Colwood, is the plant of the Silica Brick Company. Limestone is quarried south of the track, elevated over the track, and burned in down draft kilns. The resulting lime is hydrated and used in the manufacture of sandstone brick, the sand being obtained north of the track from the fore-set beds of the Colwood delta.

66·8 m.
107·5 km. **Parsons Bridge**—Altitude 99 ft. (30 m.). From Parsons Bridge to Victoria, the railroad traverses the southeast lowland of Vancouver island. This portion of the lowland is largely covered by Maywood (inter-glacial) clays with in places a thin mantle of Vashon drift, but with numerous small monadnocks or ledges of the crystalline rocks, Vancouver volcanics, Sutton limestones, and Wark and Colquitz gneisses. Three quarters of a mile east of Parsons Bridge is a limestone lens that has been quarried for flux by the Tyee Copper Company.

68·8 m.
110·7 km. **Esquimalt**—Altitude 35 ft. (11 m.). One half a mile north of Esquimalt the railroad runs

Miles and Kilometres.

along the west shore of Portage inlet, the eastern of the two drowned glaciated valleys which bound the Esquimalt peninsula. Crossing the low "Portage" the railroad runs along the western of the two drowned valleys, Esquimalt harbour. Between Esquimalt and Victoria the railroad crosses the Esquimalt peninsula. Two miles from Esquimalt on the south side of the track is the British Columbia Pottery Company's plant, where in the manufacture of sewer pipe, flower pots, etc., the Maywood clays are mixed with other more refractory clays to bring up the plasticity of the refractory clays. Crossing by a bridge the eastern drowned valley, the outer portion of which is Victoria harbour, the railroad enters the city of Victoria.

72·5 m.
116·7 km.
Victoria—Altitude 32 ft. (10 m.).

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FIRE CLAY DEPOSITS AT CLAYBURN, B. C.

By

CHARLES CAMSELL.

INTRODUCTION.

This excursion has been arranged to start from Vancouver, B.C. going by electric car over the line of the B.C. Electric railway to Clayburn, distant 46 miles (74 km.), for the purpose of examining the brick works and fire clay deposits situated at that point. These fire clay deposits are the most important known in British Columbia, and the fire brick manufactured at the works supply the market for practically the whole province.

The route of the excursion lies eastward from Vancouver, and, crossing Fraser river at New Westminster, continues on the south side of that stream through the level country which forms the delta of the Fraser.

The country embraced within the modern as well as the ancient delta of Fraser river extends from Agassiz westward to the coast, and runs southward into the State of Washington. It is on the whole low and rolling, the elevations ranging from sea level to about 400 feet (122 m.) above. Here and there, however, isolated hills, which attain elevations as high as 1,000 feet (304·8 m.) above the sea, rise above the general level of the plain. The northern boundary of the delta is the Coast range of mountains, whose slopes rise quickly from the delta plain to elevations of 3,000 (914 m.) to 6,000 feet (1,828 m.) above the sea.

The oldest exposed rocks of the region are the granitic rocks of the Coast Range batholith, which border the delta on the north. These rocks have been proved by borings at Vancouver to underlie the Eocene rocks of the delta itself.

Remnants of once more extensive Cretaceous beds occur as hills rising above the general level of the delta in its upper part near Agassiz, and around these the more recent deposits were laid. Sumas mountain, on which the clay deposits are situated is one of those.

Practically the whole of the delta is believed to be floored by stratified rocks of Eocene age, which are referred to in the literature as the Puget group. They consist of only slightly disturbed conglomerates, sandstone, shales and some lignite, laid down in an estuary as delta deposits of the ancient Fraser river. They have an estimated thickness in this region of about 3,000 feet (914 m.),and contain a variety of plant remains from which their age has been determined. This formation contains the fire clay deposits.

Overlying the Eocene beds are unconsolidated deposits, of glacial and post-glacial origin, which were laid down either sub-glacially or at the glacial front during the period of ice recession. These lie at elevations as high as 400 feet (122 m.) above sea level and consist of sands, gravel and boulder clay. They form broad, flat-topped plateaus which were at one time joined together and formed the post-glacial delta of the river. Elevation of the land relative to the sea, however, has taken place since, enabling the river to cut into the older delta so that now only detached remnants of it are to be found. This process of deepening is related to the strong terracing of the upper part of the Fraser valley. The stream is forming a modern delta in the lower part of its course at the present time, and this delta is gradually being pushed seaward into the Gulf of Georgia.

Summary of Geological History of Fraser Delta.

The history of the delta as far as our present knowledge allows us to read it may be summarized as follows:

1. Post-Lower Cretaceous revolution, followed by the development of an estuary, probably by erosion, where the delta of the Fraser river now is.

2. Deposition in the estuary of material derived by erosion from the interior, and carried down by the ancient Fraser river in Eocene times, forming the Eocene delta.

3. Gradual but continuous removal of much Eocene material in succeeding Tertiary times.

4. Glacial period.

5. Formation of Glacial delta by deposition of glacial material during the closing stages of the Glacial period.

6. Post-Glacial uplift resulting in the cutting down and removal of much of the glacial delta deposits.

7. Formation of modern delta at the mouth of the stream.

Miles and
Kilometres.

0 m.
0 km.

Vancouver—Leaving Vancouver on the British Columbia Electric railway to Chilliwack the line runs east through the suburb of Grandview, and then turns southeastward across the peninsula separating Burrard inlet from Fraser river, passing, on the way, through the suburban settlements of Collingwood, Central Park and other places to New Westminster. From Vancouver the line gradually mounts the ridge to the southeast of Vancouver and at Central Park reaches an altitude of 450 feet (137 m.) above sea level. Although this ridge is underlain by rocks of Eocene age to a depth of several hundred feet no exposures other than those of the Recent and Glacial deposits are visible from the car. These represent the remains of delta deposits laid down in the closing stages of the Glacial period. The summit of the ridge is flat and was at one time heavily forested.

Collingwood—
Central Park—
Burnaby—

Beyond Central Park, occasional glimpses can be obtained of Fraser river on the right through openings in the trees, and shortly after passing Burnaby the descent to the river is begun.

12 m.
19·3 km.

New Westminster—The town of New Westminster is one of the older places on the mainland of British Columbia, having been established in 1859. It is situated on Fraser river at tide water, and has deep water connection with the sea. It is built on the slope of a hill facing the south, having the modern delta of Fraser river directly in front and the snow covered volcanic cone of Mt. Baker, 11,000 feet (3,352 m.) in elevation, in the distance to the southeast. At New Westminster the Fraser river is crossed by a steel bridge which affords accommodation for railway as well as vehicular traffic.

Miles and
Kilometres.

12 m. 19 km. **South Westminster**—
16·5 m. 26·5 km. **Kennedy**—
22 m. 35·4 km. **Sullivan**—

Exposures of fine grained Eocene sandstone showing cross bedding are seen in the railway cuts at South Westminster. Beyond this the line gradually ascends the slope of Strawberry hill, until at Kennedy it reaches an altitude of about 300 feet (91 m.), above the sea.

Strawberry hill, like Mount Lehman farther east, is a flat topped plateau covered by unconsolidated sands and gravels representing delta deposits laid down at the close of the Glacial period. They are erosion remnants of the old delta which have not been removed by the post-Glacial deepening of Fraser river.

25·5 m. 41 km. **Cloverdale**—
29 m. 46·6 km. **Langley**—
32 m. 51·5 km. **Milner**—
32·5 m. 52·3 km. **Jardine**—

Descending the eastern slope of Strawberry hill, the line crosses Serpentine river and enters a low level country which extends along the route of the excursion as far as Jardine. This level country is only a few feet above sea level and is part of the delta built up by Fraser river in modern times when that stream emptied into Mud bay.

Cloverdale, Langley and other places on this part of the route are the centres of much good agricultural country.

35 m. 56·3 km. **Sperling**—
37 m. 59·5 km. **Coghlan**—
42 m. 66 km. **Bradner**—
44 m. 70·8 km. **Mt. Lehman**—

At Jardine the line begins to rise again to the top of another of those low plateaus built of sands, gravel and glacial material deposited in the delta of the Glacial period. This plateau is known as Mount Lehman and has an elevation of about 300 feet (91 m.) above the sea. It is heavily wooded and traversed by a number of sharp deep valleys. Sections of the deposits of which it is built can be seen in a number of places along the line of travel.

Miles and Kilometres.

46·5 m. 74·8 km. **Gifford**—
49 m. 78·8 km. **Clayburn**—

Descending the eastern slope of Mount Lehman near Gifford, the line is only a short distance from Fraser river, which can be seen on the left. Here again is low flat open country only about 20 feet (6 m.) above sea level. The railway runs for about five miles (8 km.) through this country to Clayburn station which is about one mile distant from the brick works of the Clayburn Brick Company.

From the brick works a narrow gauge railway runs up the valley of Kelly creek into Sumas mountain for a distance of about 3½ miles (5·6 km.), to the fire clay deposits. The railway is used for carrying the clay from the mines to the brick works and is operated solely for the convenience of the Clayburn Brick Company.

GEOLOGY OF THE REGION ABOUT CLAYBURN.

GENERAL DESCRIPTION.

The village of Clayburn, populated almost entirely by people employed in the mines and brick works, is situated on the western edge of Sumas mountain, about a mile from the station. Sumas mountain itself is a heavily wooded hill rising through the flat lying delta country to an altitude of about 1,000 feet (305 m.) above sea level. The central part of the mountain is made up of massive quartz porphyries which are believed to be of Lower Cretaceous age, and around this has been deposited a series of beds of Eocene age consisting of conglomerate, sandstone, shale and thin seams of coal. The Eocene beds rest unconformably on the quartz porpyhry floor, and have a gentle dip ranging from 5 to 15 degrees to the southwest. Outcrops of these rocks are rare, and on the lower slopes of the mountain they are covered by Pleistocene sands and clays.

The Eocene deposits contain the beds of fire clay which are said to be the most important on the Pacific Coast of Canada.

About 1,000 feet (305 m.) up Kelly creek from the brick works is situated a bank of clay from which material is obtained for manufacture into common brick. The section in the bank shows a bed of sand separating two beds of clay, over which is about 15 feet of river gravels. The beds are all of glacial or post-glacial origin and not firmly consolidated, so that they can be worked by a steam shovel.

Two miles (3.2 km.) beyond these clay deposits is the Thornton mine, the first mine at which the Eocene shales are worked. These beds outcrop on either side of the creek and consist of shales overlaid by conglomerate and underlaid by sandstone. The beds are of Eocene age and dip about 6 degrees to the southwest. The shale is separable into two beds which are described by Dr. H. Ries (**4**, p. 390) as "a lower grey shale of smooth plastic character, and an upper purplish one which is harder and grittier. The former is buff-burning, and on the south side of the track is at least 6 feet (1.8 m.) thick, while the upper or grey burning shale is 4 (1.2 m.) to 6 (1.8 m.) feet thick." A test of the lower shale by Dr. Ries showed it to be of good plasticity, burning to a good buff pressed brick.

A mile beyond the Thornton mine and on the opposite slope of the mountain is what is known as the fire clay mine. This was formerly worked as a coal mine and contains a seam of coal up to 3 feet (.9 m.) in thickness. The section at this mine as measured by Dr. Ries is as follows:

Sandstone....................	
Upper fire clay.................	8 ft.—2.4 m.
Coal with flint clay partings.....	6 in. to 1 ft.—.15 to .3m.
Lower fire clay.................	7 ft.—2.1 m.
Ferruginous clay...............	4 ft.—1.2 m.
China clay.....................	10 to 15 ft.—3 to 4.5m.

Only the portion between the coal seam and the china clay is at present being mined, a selected sample of which fused Cone 32. The china clay is a fine grained whitish clay fusing at Cone 22. It is not being mined.

The shales of the Thornton and fire clay mines are mined underground by pillar and stall methods, and an output of about 100 tons per day is maintained.

The capacity of the brick works is about 80,000 bricks per day, and the product of the kilns includes common, pressed and fire brick, drain tile and sewer pipe, and various other fire clay products.

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VICTORIA, BRITISH COLUMBIA, TO CALGARY, ALBERTA.

The east bound portion of C 1 Excursion follows as far as Calgary, the same route as that taken in the westward journey, the guide to which is given on pages 105 to 274 of Guide Book No. 8, Part II.

CALGARY TO WINNIPEG.

Via Canadian Northern Railway.

BY

A. MACLEAN.

INTRODUCTION.

At Calgary the excursion leaves the main line of the Canadian Pacific railway, and runs as far as Winnipeg

over the lines of the Canadian Northern railway, following a route considerably north of that traversed in the westbound journey.

This route lies towards the northern fringe of the prairie portion of the Great Plains area, through a region whose main geologic and physiographic features are similar to those obtaining in the southern part of the same region, a description of which is given on pages 77 to 99 Guide Book No. 8.

The points of interest to be seen on this portion of the excursion include: Dinosaurian bone beds at Munson, Alberta; Foraminiferal Cretaceous limestone and the beaches of glacial Lake Agassiz at Pine River, and the fossiliferous Devonian on Lake Winnipegosis, where the fauna is of a distinctly European type.

ANNOTATED GUIDE

(Calgary to Munson.)

Calgary—Altitude 3,425 ft. (1,044 m.). From Calgary the route of the excursion lies northeastward over an open rolling prairie country to Munson which is situated on a tributary of Red Deer river.

Munson—Altitude 2,600 ft. (780 m.). Here a short excursion is made to points along Red Deer river, where beds of the Edmonton formation, containing Dinosaurian remains, are exposed.

THE EDMONTON FORMATION ON RED DEER RIVER NEAR MUNSON, ALTA.

The distance from Munson to the Red Deer along the shortest route is about six and a half miles (10.5 km.) This route is directly west along the road running in an east and west direction through the town.

Owing to the proximity to Fox coulee and the Red Deer valley, the road crosses several tributary coulees on its way to the river. After crossing the first of these just outside the town, one reaches a summit from which the land slopes very gently to the banks of the Red Deer.

From this summit may be seen several of the prominent physiographic features of the region.

To the east, about 18 miles (29 km.) beyond Munson, rises the Hand Hills ridge—the most marked of all the hills to be seen from here. To the southwest of this on the other side of Red Deer valley, are the Wintering Hills, while in front—to the north and west—are the Three Hills, and still nearer Sarcee Butte. To the immediate west is the valley of the Red Deer river, and to the south and west across this valley is the rough and broken country about the Knee Hill creek, which stream flows into the Red Deer river, at a point about directly southwest of Munson.

Near Munson the subsoil is very heavy, giving the heavy waxy "gumbo" soil of the western plains, but on the last facet of the upper slope before reaching the edge of the cut banks, the soil becomes lighter and contains more sand. Both types of soil, however, have given excellent results during the period they have been cultivated.

At a point four miles (6·4 km.) to the west of Munson, one may continue for two and a half miles (4 km.) farther west and come directly to the edge of the cut banks, or turn to the south and so get a road along a fairly good grade to the river flats either at the Wigmore ferry or at the Wigmore ford—opposite the mouth of the Three Hill creek. To reach this latter place the road turns again to the west at a point one and a half miles (2·4 km.) south of the last road intersection, and finally follows a private trail down to the river flats, and then along these in front of the Edmonton exposures.

In passing down to the river flats, and in driving along them, there are several excellent examples of the different stages of denudation and erosion. On either side of the river valley several coulees and ravines have cut their sharp "V" valleys back into the table land above. Just across the river the Three Hill creek, having cut its channel down to the present base level of its mouth, has subsequently widened its valley to have a fairly extensive flat at the bottom. On the nearer (northeast) side of the river, among the Bad Land features, are many cases where the valleys in heading back from the river, have encroached on each other and have cut off one or more buttes from the table land behind. In other cases these have been worn from the flat-topped buttes to sharp ridges or conical hills, which finally pass to low rounded hummocks in the last

stages of denudation possible with the present river level.

As seen from below, the cut banks of the river and coulees and the sides of the buttes show the typical exposures of the Edmonton series. From the level of the river flats below to the grassy slope above, the light and dark coloured banks or beds are so marked and so characteristic that even from a distance of some miles one has no difficulty in detecting them and recognizing them as belonging in all probability to this formation. On close examination it is seen that the light coloured bands are greenish or yellowish gray in colour, and consist of sandstone, shale or clay, with the clay predominating.

The dark coloured bands are red or black in colour, the red bands being often similar in composition to the gray, with the exception that they have a much higher ferric iron content. In some cases this iron has been concentrated in several bands of ironstone concretions. These bands are in general from four to six inches (10 to 15 cm.) in thickness, and are distributed at various levels in different places. On the weathered bank they project from the slope for a few inches, until the nodules of which they are composed are undermined, and of their own weight fall to the bottom of the bank.

The black bands are either of a dark shale, or mark the outcroppings of different seams of coal which may be as many as six in number, although this number is not constant, since these beds are not always continuous for great distances. The smallest of these coal seams at this place is about six inches (15 cm.) in thickness, and the largest about three feet (1m.).

As exposed at the surface the coal is of poor quality, being lignitic in character. It crumbles and disintegrates rapidly on exposure to the changes of the atmosphere, but when freshly mined or when exposed under water, the quality is much better and has a wide local use. In many instances it is simply quarried or mined out of the nearest exposure by the farmers themselves, but in addition to this there are several mines which supply the towns and such of the farmers who care to buy at the pit mouth.

It is within one of these seams that the greatest amount of fossil wood is preserved. Stumps, tree trunks, and large slabs of "wood" may be found lying along the river flats near the place where they have weathered out of the coal seam.

Many of the remains are more or less silicified, and in some cases are opalized. In most cases, the structure is excellently preserved, the fossil wood being so like the modern that in many cases it is easily mistaken for a piece of recently weathered wood.

The vertebrate remains occur at a higher level, some 60 or 70 feet (18 or 21 m.) below the top of the bank. The bed containing them, varies from a yellow clay or shale to a fairly compact gray sandstone, and the state of preservation differs with the material of the bed in which it is found. Some excellently preserved specimens are found in association with the concretionary iron beds, but in these cases, it is almost impossible to separate the iron from the bone.

Owing to the fact that most of the exposures are on the steep face of the cut bank, it is sometimes difficult to find the complete set of bones in place. As the bank is eroded, some of the bones become undermined and roll to the bottom of the slope, where they lie until completely broken up by exposure. By tracing these fragments up the bank, some may be found projecting a few inches from the surface. To extract them from this bed means that a large amount of overburden has to be removed, or that the bones should be taken out by "mining".

Most of the specimens found here are reptilian, of the order Dinosaurs [**6** and **7**], although farther down the river there are reported remains of fishes and small mammals. None of these have as yet been found in this region.

The exact position of this fossil-bearing bed is often difficult to determine, owing to the tendency of the bank to break and slide to the lower levels. On these slips, erosion is often more effective than on the undisturbed levels above, so that, in some cases, the bone-bearing beds have been exposed by the butte weathering down to its level. In such cases, the task of collecting is comparatively easy.

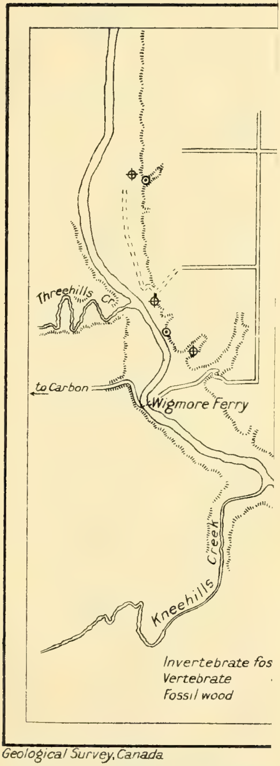
The slipping of the banks mentioned before is in this formation even more prevalent than in other regions where clay forms the greater part of the subsoil. The tendency to slip is increased by the presence of a varying amount of "bentonite" disseminated through the whole formation, and sometimes aggregated in beds of considerable thickness. This material when moist, is very waxy or soapy, and when given sufficient amount of water has a tendency to become very gelatinous and to expand excessively. The presence of

bentonite in the subsoil is probably in part the cause of the waxy nature of the "gumbo" soil, and is also responsible for a great many of the engineering problems, where difficulty is experienced in holding a road bed on the side of a cut, or even in maintaining the grade over a level prairie underlain by it.

Throughout this part of this formation there is a distinct lack of continuity in the beds. In some exposures there may be shown a regular succession of beds of clay with no sandstone apparent, while a short distance away distinct hard beds of consolidated sandstone are found interbedded with shale and clay. In some cases, the clay passes imperceptibly into the sandstone, and in other cases gradually pinches out into a thin lens, while above it the sandstone comes in again in the same manner.

On this account it is difficult to give a section which is applicable without modification throughout the whole region, but the following section as worked out by J. B. Tyrrell may be considered as fairly characteristic of the Edmonton formation in this region. [**3**].

		ft.	in.
3·0 m.	Light coloured boulder clay, including many Laurentian boulders and pebbles—at least	10	
6·0 m.	Whitish, clayey sandstone	20	
3·6 m.	Grey, carbonaceous shale	12	
·7 m.	Coal (burnt out)	2	4
4·5 m.	Whitish, clayey sandstone	15	
·7 m.	Coal (brown lignite)	2	3
7·5 m.	Light grey sandy shale with 6″ band of ironstone near top	25	
1·8 m.	Yellow, sandy shale	6	
0·6 m.	Shale, mixed with coal	2	
18·0 m.	Grey, readily weathering sandstone, with irregular masses of ironstone and reptilian bones	60	
1·5 m.	Lighter grey sandstone	5	
0·3 m.	Sandstone and ironstone	1	
7·5 m.	Light grey, rather hard, sandy shale, with irregular bands of ironstone	25	
·15 m.	Nodules of flinty ironstone, with impressions of plants	0	6
3·0 m.	Light sandy shale	10	0
0·75 m.	Hard ferruginous sandstone, containing obscure plant impressions	2	6
1·8 m.	Light grey sandy shale	6	0
·3 m.	Rather hard lamellar sandstone	1	0
33·0 m.	Light grey shaly sandstone, containing especially in the lower portion, more or less irregular bands of ironstone nodules	110	0
94·68 metres.		315	7

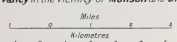


Red Deer Valley i

Excursion C3.

Geological Survey, Canada

Red Deer Valley *in the vicinity of* ***Munson*** *and* ***Drumheller***



ANNOTATED GUIDE.

MUNSON TO DAUPHIN VIA SASKATOON.

Miles and Kilometres. from Saskatoon.

The route traversed between Munson, Alberta, and Dauphin, Manitoba, is over hilly and rolling prairie underlain by Cretaceous rocks. The first section between Munson and Saskatoon is mostly prairie, while the country to the east of Saskatoon as far as Grandview is fairly well wooded. Just west of Dauphin the railway cuts through the first prairie escarpment between the Riding and Duck mountains.

The country is underlain by the Edmonton series [**3** and **4**] as far east as Richdale, then succeeded in descending order by the Fort Pierre shales which extend east to Grandview. From this point nearly to Dauphin, the country is underlain by the Niobrara shales and marls succeeded at Dauphin by the Dakota series.

Munson—Altitude 2,600 ft. (780 m.). Just west of the station a cutting in a coulee shows about six feet (1·8 m.) of stratified sand which is not consolidated to a consistent stone. Overlying it is a hard band of sandstone exceedingly rich in fossils (Ostrea). This band is about eight inches (20 cm.) in thickness, and probably owes its consistency to the presence of cementing material from the shells which form the greater proportion of the bed.

From mile posts 166-167 to the river, both sides are denuded to show typical exposures of the Edmonton formation, and the railroad enters the lower river flats at mile post 170·5.

Munson Junction—Altitude 2,604 ft. (781 m.). The Hand hills to the east rise about 1,000 feet (303 m.) above the general level of the prairie and form the most marked physiographic feature of this region. They have received their name from the resemblance which their outline bears to an outstretched hand, four or five ridges or "fingers" to the south radiating from a broader elevation, "the palm", to the north. The Indian name *Michichi*

Miles and Kilometres.

ispatinan referred to this resemblance and the idea has been retained in the English appelation —the Hand hills.

The lowest exposures of these hills show rock of the Edmonton series. Above this may be seen in some places, the brownish sandstone of the Paskapoo series, while the summit of the hills is covered with beds of Miocene age. These beds are about 270 feet (81 m.) in thickness, and this exposure is the only one of any extent in this region.

245 m.
374 km.

Richdale—Altitude 2,587 ft. (776 m.). To the west of Richdale the country is comparatively flat and the soil heavy and rather impervious, so much so that sloughs are common, and deposits of alkali are more prevalent than farther east, where the land is comparatively dry and the soil not excessively heavy. The crossing of Berry creek near Richdale marks the boundary between the Edmonton series to the west and the underlying Fort Pierre shales to the east.

Youngstown—Altitude 2,434 ft. (730 m.). East of Youngstown toward Benton, the hills form a ridge extending in a northeasterly direction. The surface generally varies from irregular to gently rolling with an almost complete absence of tree and scrub.

106 m.
170·5 km.

Brock—Through Brock and Darcy the ridges tend northeasterly. The cuttings show deposits of gravel and glacial till heavily charged with boulders.

78 m.
125·5 km.

Ridpath—West of Ridpath the railway skirts the Bad hills, and the country in consequence is somewhat rougher. Eastwards to Delisle the country is typical flat prairie, becoming more rolling on approaching Delisle and passing into a zone of hilly country to the west of Vanscoy.

505 m.
812·7 km.
from Winnipeg.

Saskatoon—Altitude 1,655 ft. (500 m.). Saskatoon lies in one of the great wheat growing centres of Western Canada, and is situated on the bottom lands of glacial Lake Saskatchewan, the eastern border of which lies about 30 miles

Miles and Kilometres.

(48 km.) to the east of the city. Neither the area nor the shore line of the lake has as yet been worked out in any detail.

278·7 m. 448·4 km. **Kamsack**—Kamsack marks the crossing of the broad valley of the Assiniboine. The divide between the Assiniboine basin and the river flowing into Lake Dauphin is reached at Shortdale. The wind gap at this point is a result of the piracy of the Valley river.

207·4 m. 333·7 km. **Grandview**—Grandview marks the upper limits of glacial Lake Agassiz. From there to Gilbert Plains the railway crosses the delta deposits formed during the highest stage of the lake.

189·4 m. 304·8 km. **Ashville**—Ashville is situated on a well marked beach of glacial Lake Agassiz. Delta deposits of a later date than the above extend from Gilbert Plains to Dauphin. The cuts along Valley river show exposures of the Niobrara formation.

177·8 m. 286·1 km. **Dauphin**—Altitude 957 ft. (287 m.).

ANNOTATED GUIDE.

DAUPHIN TO ETHELBERT AND PINE RIVER.

177·8 m. 286·1 km. **Dauphin**—Altitude 957 ft. (287 m.). Dauphin is a junction point on the line of the Canadian Northern railway from which subsidiary excursions run northward to Pine River and Lake Winnipegosis. The object of the excursion to Pine River is to examine foraminiferal Cretaceous limestone, and at the same time to view beaches of glacial Lake Agassiz which are here excellently preserved. At Lake Winnipegosis, Devonian rocks are exposed which in places contain *Stringocephalus burtoni*, a fossil common in the Devonian of Eurpoe, but only found in America in this locality and in the valley of Mackenzie river.

196 m. 313·6 km. **Sifton Junction**—Altitude 959 ft. (287·7 m.). From Sifton Junction the road takes a northwesterly course as far as Ethelbert, at which

Miles and Kilometres.

place it turns to the north-northwest, and continues this direction through Gasland, Pine River, Sclater and Cowan. Beyond Cowan the road turns to the west, following approximately the contour line in front of Duck mountain. This line is here deflected toward the west as a result of the break in the escarpment face caused by the valley of Swan river.

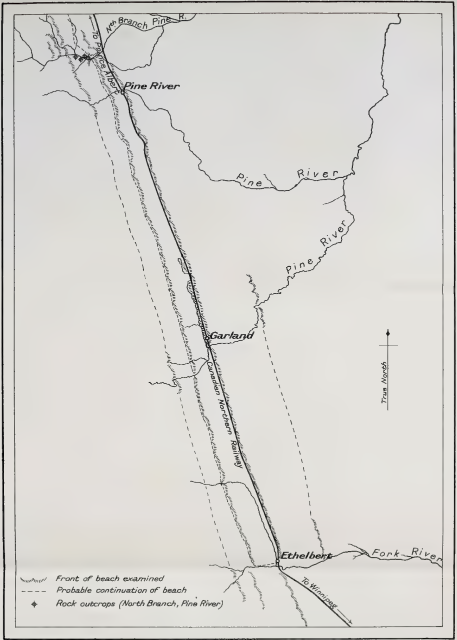
210 m. 336 km. **Ethelbert**—Altitude 1,126 ft. (338 m.). Between Sifton Junction and Ethelbert, the road gradually ascends the old bed of Lake Agassiz toward the western shore line. In this distance it doubtless crosses a number of the later shore lines of the lake formed during its recession, but in this region they are obscure and not easily recognized.

The first distinctly marked beach along this line is reached at Ethelbert, just after the road crosses Fork river and enters the town. The elevation here is 1,126 feet (337 m.), so that this shore line is 167 feet (50 m.) above the lake bottom at Sifton. At this same elevation this beach continues south for about 25 miles (40 km.), to a point about west of Dauphin. It stands out as a distinctly marked ridge, and forms the location for a government colonization road. At Ethelbert, this road turns to the west for a mile, and then follows another of the beaches which will be mentioned later, while this beach is occupied by the railroad between Ethelbert and Pine River.

At Ethelbert an opportunity is afforded to observe the relation of the beach to the surrounding country. The railway is here located on the summit of the beach, while the main street of the village is on its eastern flank. An examination of the ditches and excavations along this shore line shows distinctly the sands and gravels of a shore deposit.

About one mile (1·6 km.), to the north of the town a road running toward the east shows very good sections of other lower beaches. The first is about 300 yards, (270 m.), to the east of the track, and the second about a mile

Excursion C3



Geological Survey, Canada.

Old Beaches, Ethelbert to Pine River

Miles

Kilometres

and a half (2·4 km.) east of the railroad. The first is not very distinct, but the second is fairly well marked, and seems to be continued toward the north. In both these instances, the beaches are distinguished rather by their content than by any marked ridge or terrace effect, although this also is to be noticed by careful examination and observation.

On returning to Ethelbert and crossing that beach toward the west, there is evident a feature which is often to be noticed along these lines, that is, that the ground immediately behind and to the west of the beach is lower than the summit of the beach itself. As the general drainage of the district is toward the east, this results in a stretch of marshy land to the west or upper side of the old beach. In other cases the streams from the west, being deflected by this barrier, flow along parallel to the beach until they reach a gap which has been cut through the old shore line. In this manner the ground to the west is cut still lower, and the ridge appearance of the beach is accentuated.

One of these streams, a branch of Fork river, is to be noticed as soon as the Ethelbert ridge is crossed. Beyond the valley of this stream, the land rises slowly toward the west for about a mile (1·6 km.), till another and larger beach is met. This beach rises to a height of about 40 feet (12 m.) above the summit of railroad at Ethelbert. Throughout its length this beach is larger and better marked than the one to the south along which the railroad runs. Like that one also, the ridge—locally termed " the big ridge "—drops off sharply on the western side to the valley of another branch of Fork river. On the eastern flank the government colonization road previously mentioned, continues northward.

One mile (1·6 km.) farther to the west is another beach. Like those to the east of Ethelbert, however, this beach is also marked by a gravel bed of apparent shore origin rather than by a distinct change in elevation. The

Miles and Kilometres.

beach corresponding to this is better marked at Pine River, and may be observed there.

219 m. 350·4 km. **Garland**—Altitude 1,127 ft. (358 m.). From Ethelbert to Garland, the railroad as has been before mentioned, follows the lower of the two most distinct beaches. This beach with practically no grading, forms the road bed with the exception of a few places, where streams have broken through the ridge, and so have necessitated filling and bridging.

At Garland, an irregular trail runs to the east toward Winnipegosis. This road crosses three of the old beaches in four miles (6·4 km.) but as the country is bush covered the relative elevations of the ridges are concealed. The prevalence of Banksian pine and the light dry soil underfoot readily call attention to them, however, and subsequent examination reveals them as well marked beaches.

229 m. 366·4 km. **Pine River**—Altitude 1,146 ft. (344 m.). At Pine River a better opportunity is afforded of leaving the lower ridge, and again observing 'the big ridge' to the west, which is distant from the railroad about three quarters of a mile (1·2 km.) A rather poor trail leads across the wet heavy soil commonly found between the ridges, but when the ridge is reached, a good trail runs along it to the north. In following this trail for a mile or two in this direction, the shore line features are especially well shown.

At about 1·3 miles (2·1 km.) north of Pine River station, both ridges are cut through by North Pine river. South of this, the lower ridge had been gradually approaching 'the big ridge,' and after this interruption, has apparently lost its identity in the side of the more western one, which continues north of the river more marked than before.

After crossing the river, the main trail continues to follow the ridge, skirting the bank of the river for some distance. About one mile from the river crossing, this trail branches, the main branch continuing along the ridge

Miles and Kilometres.

and a minor trail following up the course of the river. On this trail, at about two miles (3·2 km.) from the place where the main trail crosses the river, are to be seen a series of three beaches. These succeed each other at short intervals, are very well marked, and as in many other instances are covered with Banksian pine.

Along the North Pine river are several exposures of Cretaceous rocks. A short distance above the point where the main trail crosses it, the river cuts into "the big ridge". At the base of this cutting, about 12 feet (3.6 m.) of shale is to be seen. This shale is for the most part of a dark gray colour and thin bedded, and weathers to thin flakes which rapidly disintegrate to mud. About seven feet (2.1 m.) above the water level is a thin bed of yellowish white clay, soft in texture, and having a peculiar astringent taste.

A short distance up the river and on the same side — the north—is another similar exposure. Both of these are probably of the Benton series. [**4**].

About three quarters of a mile (1.2 km.) farther up the river are two cliffs on the opposite or south shore of the river giving very good exposures of the Niobrara shales [**4**] and limestones. The shales are of a lighter colour than those of the Benton below, and the limestone might better be described as marl or at least calcareous shale. It is very rich in foraminifera, Globigerina especially being present in large numbers. In addition to these, other and larger fossils are to be found in considerable quantity. Of these, a species of Inoceramus and a large species of Ostrea are particularly abundant. [**5**, p. 102].

DAUPHIN TO WINNIPEGOSIS.

Miles and Kilometres from Winnipeg.

177·8 m. 286·1 km. **Dauphin**—Altitude 957 ft. (287 m.).

195·5 m 312·8 km. **Sifton Junction**—Altitude 959 ft. (287 m.). Sifton Junction almost overlies the contact of the Cretaceous and Devonian, and from this point to Winnipegosis the road is over the latter rock although as before no exposures are to be seen along the line of railway.

The railway here passes through a flat, wooded country which is now being opened to settlers. Through the clearings made by them occasional glimpses may be had of the escarpment to the west.

200·5 m. 320·8 km. **Fishing River**—On this branch railway two stations are passed—one at Fishing River and the other at Fork River. At these places two streams of the same names respectively cross the railway and empty into Mossy river, which stream drains Lake Dauphin and empties into Lake Winnipegosis about one half mile (·8 km.) north of Winnipegosis station.

207·6 m. 332·1 km. **Fork River**—Altitude 872 ft. (261 m.)

From Sifton north to Winnipegosis, the country is mostly settled by Ruthenians who still retain in the architecture of their churches and houses and in their methods of farming many of the ideas which they brought with them across the sea. In addition to these are a number of Icelanders settled in and around the town, and during the summer a few Indians usually move down from the Pine Creek reserve and pitch their camps near the village.

218 m. 340·8 km. **Winnipegosis**—Altitude 839 ft. (251 m.)

A lumber mill is in operation near the mouth of Mossy river, but the principal industry of the town is fishing. Some years ago this was prosecuted throughout the year, but latterly it has

Miles and Kilometres.

been restricted to the winter season, when the fish must be caught from under the ice. By means of horse and dog teams communication is maintained between the fishing stations and the village in winter, while in summer, the lake is navigated by gasoline launches, steam tugs and sailboats.

THE DEVONIAN OF SNAKE ISLAND AND SOUTH SHORE OF LAKE WINNIPEGOSIS.

The southern end of Lake Winnipegosis is underlain by the Manitoban formation of the Upper Devonian. The grey limestones of this formation are best seen at Snake island about four miles (6·4 km.) east of the town of Winnipegosis and the mouth of the Mossy river. On the south end of the island is located the Government fish hatchery. This and the buildings connected with it are the only structures erected there.

The island is about a mile (1·6 km.) in length. It is very irregular in shape, the two ends being about one half mile (0·8 km.) in width, while the isthmus which joins them is often but 50 feet (15 m.) in width. This irregular shape is probably due to the manner in which the rock outcrops at different places on the island and to the direction of the prevailing winds of the lake.

The long axis of the island lies in a direction about northeast and southwest. The outcrops all occur on the northwestern face of this axis. Three of these—two on the north end and one on the south—stand from 15 to 20 feet (4·5 to 6 m.) above the lake. In the lee of these elevations, sheltered from the prevailing west and north winds, the island has been gradually extended toward the south and east by continued marshy growths. At the middle of the island, where the rock barely comes above the surface of the lake, this protecting influence is lacking. Here only such marsh has been formed as has been able to creep in with the aid of the shelter given by the larger trees which have grown on the expansions at the ends of the islands.

The shore on the northwestern face shows no such marshy growths. The strong winds blowing from this direction tend to prevent marshy vegetation gaining a foothold on this side, while the heavy ice shoves of the

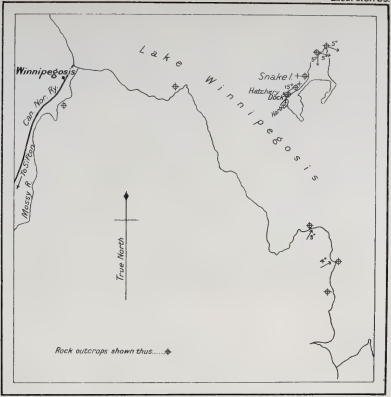
spring season serve to effectually scour out the shore and so maintain a clean gravel beach along the front. The effect of these ice shoves may be seen in the movement of some of the large boulders which lie thickly scattered along the shore, and in the long parallel ridges of non-assorted gravel which build up the beach some feet above the marshy ground beyond and behind it. These ridges may be further worked over by the waves which serve sometimes to intensify and sometimes to lessen the effect produced by the ice shove.

As already indicated the rock outcrops are five in number: two at the north end; two on the isthmus; and one on the southern expansion.

In the three exposures which stand high enough to show the dip, there is a marked inclination of the beds, varying from 5° to 15° in direction from S. 85° E. to S. 45° W. The dip in each case, however, seems to be quite local, and does not serve to bring any new beds to the surface, for in all five outcroppings the rock seems quite similar, and it is probable that there is no bed exposed on the island that is not represented in the higher of the two cliffs at the north end.

The first exposure at this end forms the northwest corner of the island, and extends for about 200 feet (60 m.) along the northeast shore, and about 300 feet (91 m.) along the the northwest shore. The dip, from 4 to 5 degrees is fairly constant in a direction about S. 80° E. to S. 70° E. This causes the beds to dip down to the shore and under the water on the northeastern side, and brings them out in a cliff on the northwestern. From the summit of this cliff, the beds gradually break away toward the southwest till they are lost under the drift and gravel of the beach.

At its highest point the cliff stands 12 or 13 feet (3·6 m.) above the water. It consists of three fairly well marked divisions. The lower four feet (1·2 m.) is a fine grained, fairly brittle limestone, light in colour and bearing a few fossils. Above this is a coarse, dark bed of limestone, very fossiliferous and from 12 inches to 15 inches (30 cm to 38 cm.) thick. A weathered section of this shows innumerable sections of brachiopod and other shells. The upper surface of this bed displays fragments of shells in all conditions of mechanical disintegration. This comminution together with wave marks shown on one of the blocks



Geological Survey Canada.

Snake Island and **South Shore** of **Lake Winnipegosis**

Miles
1 0 1 2 3

Kilometres
1 0 1 2 3 4 5

from this level, would indicate that this bed at least was formed at a depth within the limits of wave action.

In some places the succeeding beds are separated from this by a thin layer of shale 0·4 inches (1·cm.) thick. These upper beds are similar to the lower five feet, but are darker, not quite so fine grained, and are perhaps more fossiliferous.

They are seen to better advantage in the next exposure to the southwest, where a cliff about 20 feet (6 m.) above lake level shows a total thickness of 12 or 13 feet (3·6 or 4 m) above the fifteen inch (38 cm.) fossiliferous bed previously mentioned. In a bed at the summit of the cliff, 11 feet (3·3 m.) above this middle layer, are shown some of the star shaped sponge spicules.

Astreospongia hamiltonensis occurs abundantly in a single bed of the limestone.

Other fossils which have been collected here include the following:—*Cyathophyllum vermiculare* var. *praecursor*, *Alveolites vallorum*, *Atrypa reticularis*, *Atrypa spinosa*, *Cyrtina hamiltonensis*, *Paracyclas elliptica*, *Raphistoma tyrrellii*, *Bellerophon pelops*, *Euomphalus subtrigonalis*, *Omphalocirrus manitobensis*, *Hyolithes alatus*, *Gomphoceras manitobensis*, *Cyrtoceras occidentale.*

The cliff mentioned appears, as seen from the lake, to be a section across an anticline. On closer examination, it appears to be a section through a dome some distance beyond the centre. The apparent dips along the face, which at either end bring the beds up from the shore level, are but the components in this plane of the angles of dip which would radiate from the centre of the dome.

Below this cliff a great many of the blocks are from the middle highly fossiliferous bed, which appears more resistant than the other beds. On one of these blocks are shown distinct curved wave marks, three crests and three hollows, the distance from crest to crest being about 18 inches (45 cm.) and the depth of the hollow below the crest about four inches (10 cm.).

Farther to the south flat lying exposures are shown, one at each end of the isthmus. They appear to be horizontal and probably represent beds near the middle of the cliff before mentioned.

On the southern end of the island, just at the hatchery dock, is the last rock outcrop. This dips comparatively sharply towards the southwest, the angle of inclination varying from 15 degrees to 30 degrees. In all a total

thickness of about 12 feet (3·6 m.) is exposed. These beds seem to be similar to those shown in the upper half of the 16 foot (4·8 m.) cliff on the north end of the island.

Other outcrops of the rocks here described are to be seen on the south shore of Lake Winnipegosis adjacent to the island. As may be noticed on the map one of these is directly west, and the others directly south of the south end of the island.

None of these exposures exhibit any features not shown at that place, with the exception perhaps of those immediately south which may contain more fish remains than the outcrops on Snake island. These remains are probably of *Dinichthys canadensis* mentioned by Tyrrell in his report on the island. [**4** p. 163.]

The vicinity of Winnipegosis and Snake island is particularly interesting from the standpoint of the development of the knowledge of Western geology for "It was here that Prof. H.Y. Hind [**1.**] in 1858 made the collection of fossils which first determined the existence of Devonian in Manitoba." [**4** p. 163]. In the same year a report was made on the occurrence of rock on the island by A. W. Wells [**2.**]. In the summer of 1889, the island was visited and reported on by Tyrrell [**4.**], from whose report the references just cited have been taken.

THE DEVONIAN OF DAWSON BAY, LAKE WINNIPEGOSIS.[a]

Dawson bay is a large pocket-like expansion extending west and south from the northern end of Lake Winnipegosis. This bay is excavated wholly in Devonian rocks and the numerous exposures on its islands and shores and along Red Deer river show the whole of the Devonian section so far as it is known. This makes Dawson bay the most favourable region in which to study the Devonian section of Manitoba.

A spur leaving the main line of the Canadian Northern at Mafeking reaches the bay at the mouth of Steep Rock river. From this point the localities to be mentioned will be reached by gasoline launches.

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a This excursion is contingent on the completion of the branch railway from afeking to the mouth of Steep Rock river.

The basal beds of the Devonian, which rest upon Silurian limestones northeast of the entrance to Dawson bay, are not known to be exposed about the north end of Lake Winnipegosis. The Devonian section of this region includes two formations, the lower is a dolomitic limestone, estimated to be 200 feet (60 m.) thick, called the *Winnipegosan* of middle Devonian age. The upper formation is chiefly a non-magnesian limestone, but it includes some shale, and has a thickness of about 210 feet (64 m.). The younger Devonian formation has been called the *Manitoban.* The lower Devonian appears to be absent from this region. The sharp dips of 5 to 20 degrees seen at some localities have only local significance. The general dip of the rocks of this region is westerly and amounts to probably not more than 40 feet (12 m.) per mile.

It follows, therefore, that the outcrops showing only the lower formation of the Devonian lie mainly on the eastern side of the bay.

A typical exposure of the Winnipegosan dolomite is shown in the cliff at Whiteaves point 10 miles (16 km.) east of the mouth of Steep Rock river. Whiteaves point is a cliff of white compact dolomite with a maximum height of 31 feet (9·4 m.) above the water, and extends a mile along the shore. Beautifully preserved fossils occur in abundance in this dolomite. Among the common and characteristic forms are *Stringocephalus burtoni* and *Gyroceras canadense.* The first named species, although a familiar middle Devonian fossil in Europe, is known in America only in the Devonian of Manitoba and Mackenzie River valley. It is nearly everywhere a common fossil in the Winnipegosan dolomite, but does not range upward into the Manitoban formation. Another excellent exposure of the *Stringocephalus* dolomite occurs at Salt point four miles (6·4 km.) west of Whiteaves point. About 30 feet (9 m.) of white dolomite, weathering yellowish, are exposed in the cliff here. The fauna includes a considerable number of species, among which may be noted *Sphaerospongia terssellata, Columnaria disjuncta, Atrypa reticularis, Gypidula comis, Stringocephalus burtoni, Kefersteinia subovata,* and *Paracyclas antiqua.*

The Manitoban or upper Devonian formation is exposed in several cliffs and points to the north of the mouth of Steep Rock river within a few miles. One of the best sections is exposed at Point Wilkins. Point Wilkins, which

is four miles (6·4 km.) north of Steep Rock river, rises 80 feet (24 m.) above the lake. The cliffs here expose the following beds of the Manitoban formation:—

b. Light grey, fine grained, thin-bedded limestone, some beds breaking with conchoidal fracture, 45 ft. (13·7 m.)

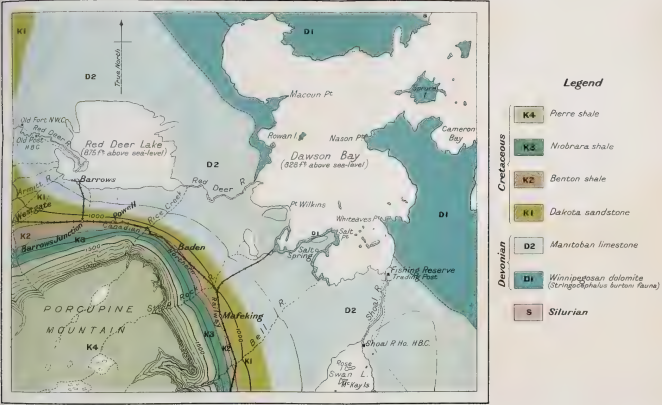
a. Light ash grey, argillaceous limestone 35 ft. (10·6 m.)

The species which are most abundant in the lower beds (b) are *Atrypa reticularis* and *Paracyclas elliptica*. The upper beds contain a very sparse fauna, in which *Athyris vitata* is one of the most abundant species. *Stringocephalus burtoni* and many of the other fossils of the Winnipegosan dolomite are unknown in this upper formation.

An interesting feature of the Point Wilkins section is the brecciated beds which appear very near the southern end of the cliff. Here, where the cliff has a height of only about 25 feet (7·6 m.), the horizontal and undisturbed limestones pass abruptly into a belt of limestone which has been broken into large angular blocks; these have been more or less completely recemented together. Some of the interspaces are filled with a light grey micaceous sandstone. There are no Devonian beds in any part of the section which resemble this sandstone filling. It probably represents material which sifted into the interstices of the breccia during the deposition of the Dakota formation of the Cretaceous, which further westward overlies the Devonian limestone.

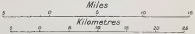
Immediately south of the Point Wilkins cliffs, and a few rods from the brecciated limestone an old forest-covered beach of comparatively recent date rises about 15 feet (4·5 m.) above the surface of the lake. Another and much older beach or bar 6 to 8 feet (1·8 to 2·4 m.) high extends across the top of the cliff 100 to 200 yards (91 to 182 m.) back of its face. This beach stands about 85 feet (26 m.) above the level of the lake. The present high stage of the lake is indicated by the line of dead birches now standing on the edge of the lake along the foot of the Point Wilkins cliff on the northeast side.

Numerous salt springs issue from the Devonian limestone at various points along the streams entering the west side of Dawson bay. North of the mouth of Bell river, two and three quarter miles (4·4 km.), a small brook enters the lake which is estimated to discharge into the lake $37\frac{1}{2}$ tons of salt every 24 hours [**4.**]. The salt beds thus indicated in the Devonian are known only through the saline springs.



Geological Survey, Canada

Dawson Bay



ANNOTATED GUIDE.

(Dauphin to Winnipeg.)

Miles and Kilometres from Winnipeg

177·8 m. 286 km. **Dauphin**—Altitude 957 ft. (287 m.). Dauphin lies about 177 miles (286 km.) northwest of Winnipeg, and is situated just to the east of the first prairie escarpment which marks the boundary between the flat floored valley of glacial Lake Agassiz and the second prairie steppe. This escarpment, in its southern extension to the southwest of Ochre, is known as Riding mountains, and continues northwards under the name of Duck and Porcupine mountains, the three groups being separated by the cross valleys of Valley and Swan rivers. The escarpment has been formed by aqueous erosion of the almost horizontal Cretaceous rocks overlying the Palæozoic which forms the major portion of the bed rock floor of Lake Agassiz.

Between Dauphin and Winnipeg the railway crosses the following series. From Dauphin to Ochre the road is underlain by the Dakota series, succeeded by Devonian limestone which extends to Makinak. Between Makinak and Laurier the railway again crosses the Dakota and the approximate contact between the Benton and Dakota is about six miles (9·6 km.) north of McCreary. Between McCreary and Gladstone the country is underlain by the Benton shales, succeeded at the latter point by the Dakota sandstone, the lowest series of the Cretaceous, which extends as far as Beaver. From Beaver to Portage la Prairie the underlying rock is Devonian. East of Oakville toward White Plains the country is underlain by the Silurian, no outcrops, however, occurring adjacent to the railway.

140 m. 225 km. **McCreary**—

92·6 m. 149 km. **Gladstone**—

55·5 m. 89 km. **Portage la Prairie**—

From Headingly to Winnipeg, the underlying rock is Ordovician limestone and shales.

0 m. 0 km. **Winnipeg**—Altitude 761 ft. (232 m.).

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WINNIPEG TO PORT ARTHUR.

BY

A. L. Parsons.

ANNOTATED GUIDE.

(Winnipeg to Kenora).

Miles and Kilometres.

0 m.
0 km.

Winnipeg—Altitude 757 ft. (230·7 m.). The level, treeless prairie at Winnipeg, representing the former bed of glacial Lake Agassiz, extends eastward along the Canadian Pacific railway to Darwin. In this distance, however it gradually changes to a somewhat rolling, heavily forested country and, eventually, at Darwin, gives place to the hummocky, glaciated

Miles and Kilometres.

rock surface of the Pre-Cambrian shield. The underlying Ordovician limestone is hidded except at Tyndall and Garson, where quarries may be seen at some distance from the railway.

69·5 m. 101·8 km. **Darwin**—Altitude 972 ft. (296·3 m.). From Darwin to Summit, a total distance of 340 miles (547 km.), the route crosses a region underlain by alternating stretches of Keewatin schists and Laurentian granite-gneisses that present no points of particular interest. The solid rocks are covered more heavily than usual with boulder clay and stratified clays, and consequently the topographic relief is even less than in most parts of the Pre-Cambrian shield. Rock-bound lakes are very numerous.

132·7 m. 213·5 km. **Kenora**—Altitude 1,088 ft. (331·6 m.). The Keewatin-Laurentian contact lies not far to the north of the railway in the vicinity of Keewatin and Kenora. In consequence of this, the Keewatin schists have been contact-metamorphosed into highly crystalline hornblende schists and gneisses.

A fine view of Lake of the Woods is obtained just as Kenora is entered. This town, the largest between Winnipeg and Fort William, is the business centre for mining, lumbering and milling industries in the Lake of the Woods district.

PRE-CAMBRIAN GEOLOGY IN THE NORTHERN PART OF LAKE OF THE WOODS.

General Geology of the Region.

The northern part of the Lake of the Woods is characterized by rocky shores, numerous islands and a rugged topography, though the elevation of the highest hills above the level of the lake is seldom more than 150 feet (45 m.). Though most of the islands and the main shore are covered with a dense forest growth, principally of second growth spruce, jack pine (P. banksiana), and birch, there is as a rule not a great depth of soil overlying the rock, which can be seen almost

continuously along the shores. The rugged relief of this northern part of the lake is in decided contrast to the region south of Grande Presqu'ile, where many sandy beaches and dunes and high rocky shores are uncommon.

According to Dr. A. C. Lawson (**1**), to whom our geological knowledge of this district is chiefly due, the Pre-Cambrian rocks are separable into four principal groups: Keewatin; Laurentian; a series of granites younger than the Laurentian; and Keweenawan.

KEEWATIN.

The oldest of these formations, the Keewatin, is divided for purposes of mapping into four divisions which appear to be lithologically distinct, but at times grade so imperceptibly from one to another that it is well nigh impossible to draw hard and fast boundaries. These are:— (a) Hydromicaceous schists and nacreous schists, with some associated chloritic schists and micaceous schists, and including areas of altered quartz porphyry.

(b) Clay slate, mica schist and quartzite, with some fine grained gneiss.

(c) Agglomerates and other coarse clastic rocks, all more or less schistose and generally of volcanic origin.

(d) Hornblende schist and altered trap, with some chlorite schists of volcanic origin.

In addition to the above, some bands of carbonaceous schists and ferruginous dolomite and possibly some serpentine are included in the Keewatin.

Of the four principal divisions the last two are definitely referred by Dr. Lawson to an irruptive origin; the first is said to have been laid down by sedimentation, though probably originally volcanic, and the second is assumed to be of a sedimentary origin.

Hydromica Schists, Nacreous Schists, etc.—Dr. Lawson seems to consider that the members of this sub-group are largely sedimentary, though originally volcanic (volcanic ash beds). He recognizes quartz porphyry as the original rock from which part of the series was derived. The writer's study would indicate that they resulted largely from the alteration of a diorite or andesite similar to the more acidic portions of the ellipsoidal trap. In the development of these schists, the rock passes through a stage which has been called agglomerate, though this term

is made to include two classes of rock, friction breccias or autoclastic rocks and volcanic breccias formed where a dark lava has intruded the older lavas. The friction breccia is the common intermediate stage in the development of the sericite schists. These schists with the breccia agglomerate are shown on the unnamed island west of Queer island, also upon Slate island in the vicinity of a Keweenawan dyke.

A marked feature of these schists is the prevalence of ferro-dolomite or ankerite, which in some cases forms vein-like masses as much as 20 feet (6 m.) in width. As a rule this material is not pure, but contains streaks of sericite or chlorite and some quartz. Its weathered surface is ochre yellow and of striking appearance. Good examples of ferro-dolomite can be seen on a small island east of Pipestone point and north of Square island, on the mainland east of Square island, and on an island east of Whiskey island. Another conspicuous band of this material is shown on the west side of Middle island.

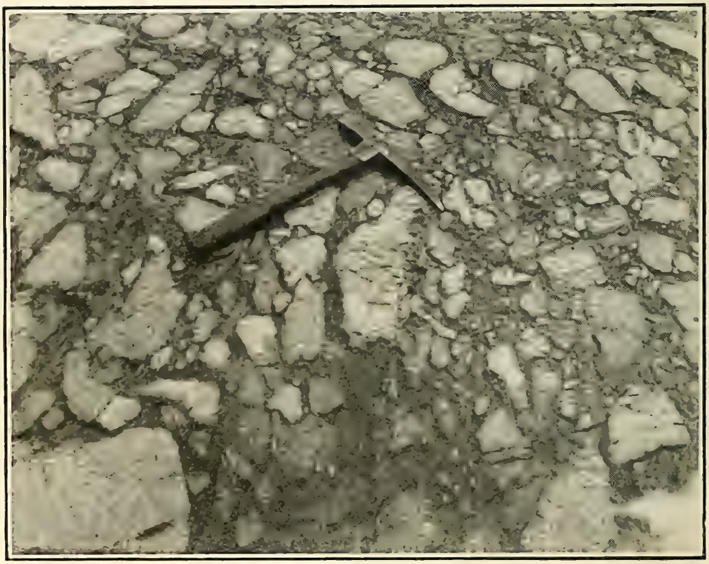
Clay Slates, etc.—This subdivision consists principally of highly altered hornblende and biotite schists which may or may not contain garnet. In some instances true slate has been found, but this is only in small quantity. In regard to making a distinct division of the Keewatin to include these rocks there is considerable diversity of opinion. It may be said, however, that they have been found principally in close proximity to Laurentian masses or to the later (?) granites and there seems to be no objection to considering them merely as highly altered phases of the ordinary Keewatin traps. In numerous instances this rock contains large veins of pyrrhotite which have been prospected for gold, but as a rule these deposits have been found to be of no economic value.

In certain places on West Hawk lake these highly altered rocks (**7**, p. 202) seem to be of sedimentary origin, but so far as partial analyses of rock from Lake of the Woods show (**7**, p. 179), the rocks of this subdivision found there are probably of igneous origin.

This highly altered rock outcrops near Keewatin and Norman. It underlies the town of Kenora and continues thence in a northeasterly direction for about six miles (9·6 km.).

Agglomerate.—Under this title are grouped fragmental rocks of extremely varied texture and origin. The more

common type of agglomerate appears to be merely a brecciated Keewatin trap or andesite which grades into sericite schist. This rock is usually light coloured, and is well developed near the Keweenawan dyke on the unnamed island west of Queer island. Through a cartographic error this outcrop was shown on the older maps as clay slate.

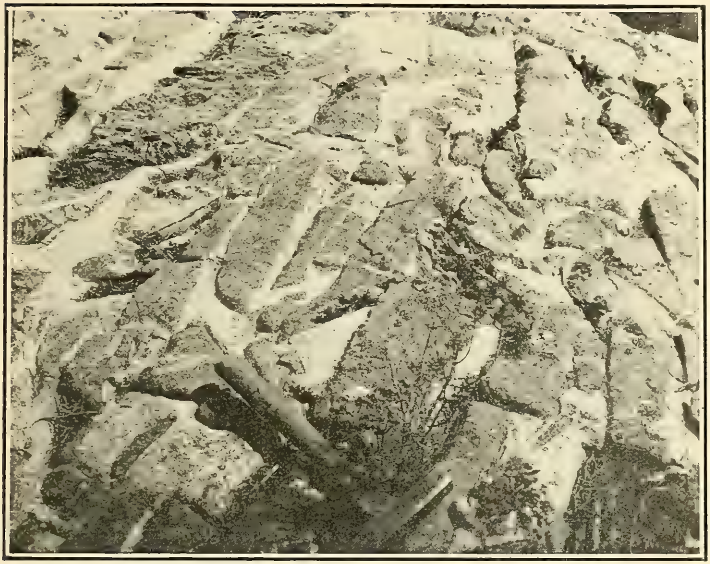


Agglomerate; Kenora, Ont.

The other principal type of agglomerate is also a breccia, but in this case the brecciation is probably caused by a flow of dark lava which has broken off fragments of solid rock and cemented them together. It is possible, however, that this type is due to the falling of volcanic bombs and ash into molten lava, though the gradation from the ellipsoidal trap to agglomerate on the east side of Ash bay would strengthen the former suggestion. This type of agglomerate is well exposed near the old saw-mill in Kenora.

Altered Traps, Hornblende Schists and Chlorite Schists.—These rocks, which are by far the most widely distributed of the Keewatin rocks in this region, are probably all of the same origin. In general it may be said that

these ancient traps are diorites (or diabases in some instances) with an ellipsoidal or pillow structure. In places that have been badly weathered, this structure is sometimes obscured, but careful search will usually reveal it even when the trap has been largely altered to chlorite schist. The ellipses usually consist of a light coloured

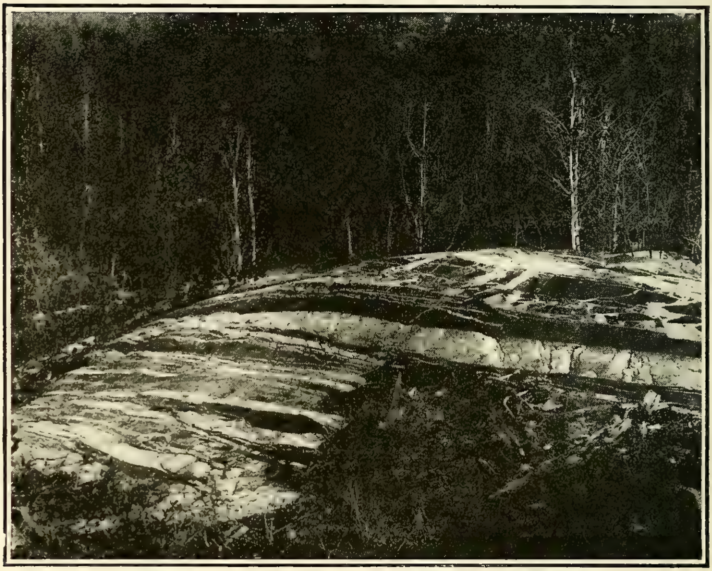


Contact breccia, Keewatin and Laurentian. Barry lake.

interior and an outer band of dark material which appears to be a basic segregation, though both portions can be classed as diorite. In the interstices between the ellipses is a filling of ferro-dolomite or ankerite with some quartz and frequently a considerable quantity of epidote. Rocks of this character are particularly well shown at Devil's Gap and on the west side of Big Stone bay from the Keewatin mine to Eagle passage. In these places the typical ellipsoidal structure is well developed. In other places the squeezing of these ellipses in the alteration of the rock to chlorite schist and in certain instances to sericite schist is beautifully shown.

At the contact of the Keewatin with the Laurentian there is found usually, if not always, a hornblendic rock

which is considerably brecciated and evidently resulted by recrystallization of the ancient traps. This type of material is to be seen near the Sultana mine and on the west side of Bottle bay, where domes of granite show nearly every possible phase of this rock from the slightly altered trap with pillow structure to the brecciated hornblendic rock



Brecciated contact, Keewatin and granite. Sultana mine.

included in domes of granite. Sometimes even the granite domes are free from it except near their margins. To the west of the small indentation on the north side of Andrew bay, several of these granite domes, with the brecciated hornblendic rock grading into the ancient traps, are to be found. These domes have the typical "roches moutonnées" structure and have evidently been denuded by glaciation, but it is of interest to note that the resultant form has been determined not by the ice but by the original intrusion of the granite. Examples of this structure are extremely common in other parts of Lake of the Woods particularly along the shore of Grande Presqu'ile. These however are beyond the limit of the excursion.

LAURENTIAN.

The Laurentian formation in the Lake of the Woods region is represented by large areas of granite and gneiss. This group is almost entirely lacking on the shores of the northern part of the lake, though there are several granite outcrops which may belong to it but have been referred to a later period by Dr. Lawson. If, however, the trap dykes, which are elsewhere described, are to be assigned to the Keweenawan it will probably be necessary to refer part of this granite, to which a later origin has been assigned, to the Laurentian. This would apply to the outcrop on Micrometer island, where the trap cuts the granite, and it would probably apply to all the granite in the northern part of the lake.

Typical Laurentian granites and gneisses are to be seen from the train on the Canadian Pacific railway at Margach (formerly Rossland) and west of Darlington bay near Keewatin. In the present excursion no outcrop of unquestioned Laurentian rock is visited, though probably the granite at the Sultana mine is to be so classed. There is an extensive development of rocks of this age north of Kenora and in the region to the east of Route bay. The most interesting area, however, from many points of view is the Grande Presqu'ile, which is essentially a series of domes of granite and gneiss with margins of highly altered Keewatin trap, and may be compared with the granite outcrops on the north side of Andrew bay and on the west side of Bottle bay. In the Andrew bay outcrops the granite protrudes through the surrounding traps in large dome-like masses which, near the contact with the trap, contain numerous fragments of re-crystallized trap, while at Bottle bay some of the domes are overlain by arched masses of the older trap, and others are like those to the north of Andrew bay.

The character of those granite masses can probably be best studied near the Sultana and Ophir mines. There the texture varies from that of a coarse granite porphyry to a granitic and even microgranitic texture. Near the contact with Keewatin traps there are places where it is difficult to distinguish the two rocks, as both are fine grained and have possibly undergone an interchange of material which seems to furnish a gradation between them. This however, is not the usual case; ordinarily the contact

is a brecciated one of no great width, the Laurentian is granitoid and the adjoining Keewatin is a dark finely crystalline hornblende schist or diorite.

LATER GRANITE.

Several of the above mentioned outcrops of granite, supposed to be later than the Lauientian, have been minutely described by Dr. Lawson, but the distinctive characters by which they may be distinguished from the Laurentian granites are apparently lacking in the exposures to be visited.

KEWEENAWAN.

A remarkable series of dykes crosses Lake of the Woods and Shoal lake in a general northwest and southeast direction. The continuation of some of these in Rainy Lake region gives a length of about 100 miles (161 km.) to some of the better developed dykes.

These dykes are essentially a coarse grained quartz diabase with a porphyritic border. In the original description (**2**), garnet is mentioned as one of the prominent minerals in the central portion, but this has not been found in the material secured by the writer from outcrops of Lake of the Woods. The other minerals observed as well as the characteristic texture of the rock, agree with the description given by Dr. Lawson. In the northern part of Lake of the Woods four of these dykes are known, while in Welcome channel a fifth dyke, that has been altered to serpentine, may possibly upon further study be correlated with these.

The adjacent Keewatin rocks usually show marked metamorphism for 20 to 30 feet (6 to 9 m.) away from the dykes. This is more evident in sericite schists containing ferro-dolomite, though is is also to be observed in the chloritic schists. As a result of this metamorphism the schists are crumpled, and epidote, magnetite and hematite, which are readily noticed in the field, are formed.

The most accessible of these dykes is that which was mapped on Thompson island and Whitefish bay. It has been traced almost without interruption from Darlington bay to the east side of Whitefish bay, and is apparently continuous with a dyke on Crow lake. In places, as on

Allie island, the rock is much decomposed, giving a chloritic or serpentinous mass in which native copper is found, though this material has not been observed in the unaltered rock.

Gold Mines of the District.

For about thirty years the region around Lake of the Woods has attracted more or less attention on account of discoveries of gold, and mining has been carried on with varying degrees of success. Several very rich pockets have been found, and gold to the amount of about two million dollars has been recovered from the mines on this lake and Shoal lake. At the present time there is little activity, though the Cameron Island mine and the Canadian Homestake mine are developing on low grade ore.

The best known mines of this region are: the Mikado, with a reported production of about half a million dollars; The Regina or Black Eagle mine, with a production about equal to that of the Mikado; and the Sultana mine, with a production estimated between seven hundred thousand and a million dollars. At the time of writing none of these mines are being worked. In all three the veins fill fissures which cut across the contact between granite and Keewatin traps. The vein material is largely quartz, but with this is a large quantity of ferro-dolomite which weathers to a rusty brown on exposure to the atmosphere.

Itinerary.

The following itinerary has been selected to show characteristic examples of the different formations described by Dr. Lawson. Two minor formations, the carbonaceous schists and the serpentine, are omitted, as they are too far distant to be reached in a trip of one day.

At the long pier near the residence of Captain H. A. C. Machin is a remarkably fine outcrop of agglomerate which shows large fragments of acidic rock in a paste of darker, more basic rock. It has been supposed by some that this is a conglomerate of water-worn pebbles and boulders, but, although there is no apparent means of determining the origin of this rock at this place, its derivation is well shown in the neighbourhood of Ash bay as probably being from a volcanic breccia.

Leaving the agglomerate the route lies through the beautiful islanded part of Lake of the Woods which extends for about 10 miles (16 km.) from Kenora. On the mainland is a large brick school devoted to the education of Indians, while the cottages of the summer residents are to be seen on nearly every island. A narrow channel, known

The Devil's Gap.

as Devil's Gap, separates Rat Portage bay from the main part of the lake, and in passing through it the peculiar landmark which gives this channel its name is seen on the left. The rock along the shores is the characteristic ellipsoidal trap of the Keewatin, though the ellipses are not so marked as some that are to be seen later. Although showing a well preserved elliptical structure, all these rocks when broken exhibit a schistose structure. On a small island on the left of the channel is an outcrop of felsite which is probably connected with the Laurentian.

On the mainland to the left is an exposure of trap which has been referred to a later age by Dr. Lawson. This trap is so distinct in appearance from the other later traps and so similar to the recrystallized traps in contact with

the Laurentian granite that it seems doubtful whether it is not merely a highly metamorphosed Keewatin trap. Strength is give to this supposition by the proximity to the felsite just mentioned and to the granite to be seen a little later on the mainland. The dome-like outline of the outcrop is also suggestive of the granite domes to be seen in Bottle bay.

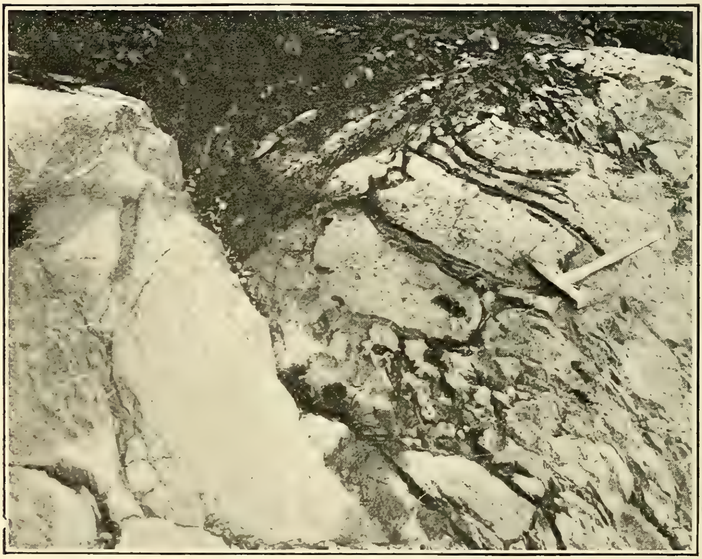
A good view of the Manitou stretch to the right gives an idea of the large, open portions of the lake, while to the left the protected waters of Matheson bay are to be seen. All the mainland between Devil's Gap and the Sultana mine is an Indian reserve, and here is a forest growth of Norway and white pine that has not been affected by lumbering operations. Here also is an Indian village with its characteristic primitive construction in effective contrast with that of a modern house that stands in the same village. Various types of tepees or wigwams are to be seen, though the covering may be lacking, as it is customary nowadays to cover the frames with canvas. The frames, consisting of four inclined poles meeting at a point with horizontal cross poles, were used in smoking and drying of meat.

Just beyond the Indian village lies Bare point, where the darker traps give place to an exposure of sericite schist which may be traced along the shore for about two miles (3·2 km.). This outcrop however is not easily accessible in a launch. At Quarry island the rock changes to a granite of the same character as that at the Sultana and Ophir mines.

From the Sultana mine a walk of about a mile affords an opportunity of studying the contact of the granite with the Keewatin. Three hundred feet (91 m.) north of the landing is a pyrrhotite vein about 10 feet (3 m.). wide, in what appears to be a quartz porphyry. The old dumps and the mill furnish interesting material for study.

Following a trail from the Sultana mine, the contact between the granite and the Keewatin and the gradation from a fine grained granite to a coarse granite porphyry may be observed. From the summit of the hill above the Sultana mine a comprehensive view of the northern part of the lake is obtained. On reaching the Ophir mine comparatively unaltered specimens of the granite porphyry may be secured on the dump, where it is also possible to find specimens of quartz showing free gold.

In a southeasterly direction from the Ophir dock beyond a fishing station and the south end of Sultana island is Needle point, where the ancient traps have been so altered that nearly all trace of their original structure has been lost and they appear as hornblendic and chloritic schists. Just beyond this point is the old Keewatin mine,



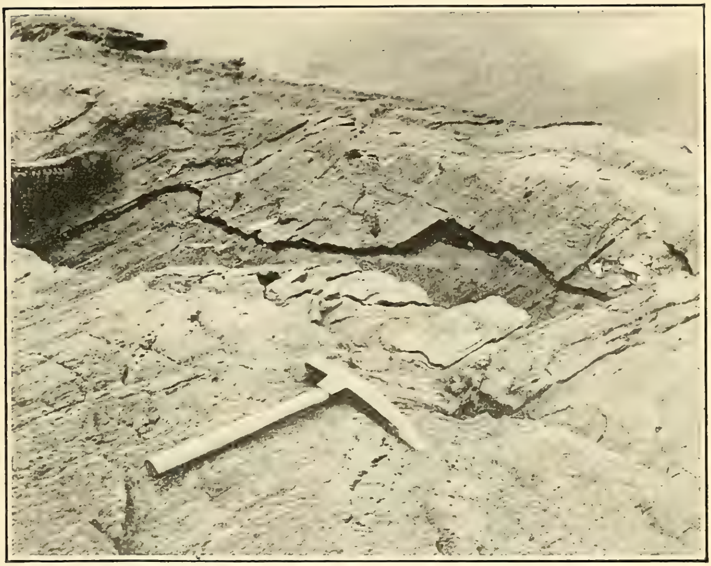
Ellipsoidal trap. Shoal lake.

where the ellipsoidal character of the trap is well shown as the result of the weathering out of the interstitial material. These ellipsoids, when fresh, are usually light coloured in the middle and dark on the borders, while the interstices are filled with quartz, ferro-dolomite and epidote. Usually the interstitial material is lacking on the weathered surfaces.

At the south side of Big Stone bay southeast from the Keewatin series, some of the precipitous outcrops of trap show the ellipsoidal structure with the accompanying ferro-dolomite. The best examples lie between high and low water marks.

Continuing along the south shore of Big Stone bay the route lies through Eagle passage and thence in a south-

westerly direction to Pipestone point, where sericite schist is prominently developed, likewise an abundance of ferruginous carbonate which in some cases is abundant enough to suggest a low grade iron ore. Such an outcrop is found on a small island just east of this point, where apparently it has resulted from the alteration of a Keewatin



Metamorphosed sericite schist; Slate island, Lake of the Woods.

porphyry. Another outcrop of this same material occurs on the mainland east of Square island.

Crosssing Andrew bay from this place a peculiar tepee made of split logs and covered with brush and earth may be seen near the entrance to Bottle bay. Entering Bottle bay the rock is a breccia agglomerate passing into sericite schist. This is followed by darker traps (on the west side). some of which are recrystallized and folded over granite bosses. Farther south the granite bosses are to be observed without the covering of trap, but occasionally a contact breccia is seen where the granite has intruded the trap. These bosses are in the form of 'roches moutonnées' and have undoubtedly been subjected to severe glacial action, but the factor determining the resultant form is apparently

the original shape of the granite boss rather than glacial action.

On the unnamed island just west of Queer island a trap dyke of probable Keweenawan age cuts an agglomeratic sericite schist. Specimens of this rock, showing the fine grained porphyritic material near the edges and the coarse diabase near the centre, are readily obtained, but it is difficult to get good contact specimens. These latter however may be secured on Slate island, where the same dyke cuts the same type of country rock, and a contorted metamorphosed zone about 30 feet (9 m.) wide is present. This metamorphosed rock closely resembles the rocks mapped as clay slate, etc., but the adjoining unaltered rock is sericite schist and agglomerate containing an abundance of carbonates. It is again seen at the contact of the same dyke on Thompson island, though the adjoining rock retains the ellipsoidal structure to a greater extent than on Slate island. Leaving Thompson island the route lies through the Keewatin channel to the north side of Rat Portage bay (on mining location K. 85), where highly altered Keewatin rocks mapped as clay slates, etc., are well developed on the shore. These are principally hornblende and biotite schists, in some places containing an abundance of garnets and intersected by large veins of pyrrhotite. These rocks are principally developed near the contact with the Laurentian granites.

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ANNOTATED GUIDE.

Miles and Kilometres.

188·3 m. 302·7 km. **Vermilion**—Alt. 1221 ft. (372·2 m.). Eagle lake another large example of the rock-bound lakes so characteristic of Pre-Cambrian regions, is seen at Vermilion. Gold is mined in the Keewatin schists at several points on this lake.

214·9 m. 345·8 km. **Dryden**—Alt. 1220 ft. (371·8 m.). Between Minnitaki and Wabigoon the Pleistocene deposits, either of boulder clay or of stratified clay, are unusually thick and support a scattered farming community. At Dryden the stratified clay is used also for brick making. Gold mines, including the Laurentian mine, are located at a number of points in the country to the south and southeast of Dryden, but none of these are near the railway.

277·9 m. 448·4 km. **Ignace**—Alt. 1487 ft. (453·2 m.).

385·9 m. 621·1 km. **Buda**—Alt. 1472 ft. (448·7 m.).

Keewatin volcanics and their schistose equivalents are continuous from near Buda to the neighbourhood of Summit, where they are unconformably overlain by flatlying Animikie sediments. But from this station to Port Arthur, a distance of 18 miles (29·0 km.), the railway traverses a flat delta plain terminating at Lake Superior, and rock exposures are infrequent. In places a red soil has been formed by weathering of Animikie iron formation, where that formation lies at no great depth. Although there are no outcrops near the railway, the horizontal Animikie sediments and the Keweenawan diabase sills intrusive into them

Miles and Kilometres.

form peculiar flat-topped hills not far to the south. These mesa-like hills are capped by portions of the horizontal sills, which resist erosion better than the slates. Mount McKay, which is seen to the south as Fort William is entered, is a splendid example of this type of topography.

426·3 m. 686·2 km. **Fort William**—Alt. 607 ft. (189. m.).

430·6 m. 693·1 km. **Port Arthur**—Alt. 608 ft. (189·3 m.). Lake Superior is in sight all the way between these towns.

PORT ARTHUR TO TORONTO.

From Port Arthur to Toronto the excursion follows the same route as that taken in the west-bound journey, a guide to which is found on pages 13 to 36 of this Guide Book and in Guide Book No. 6.

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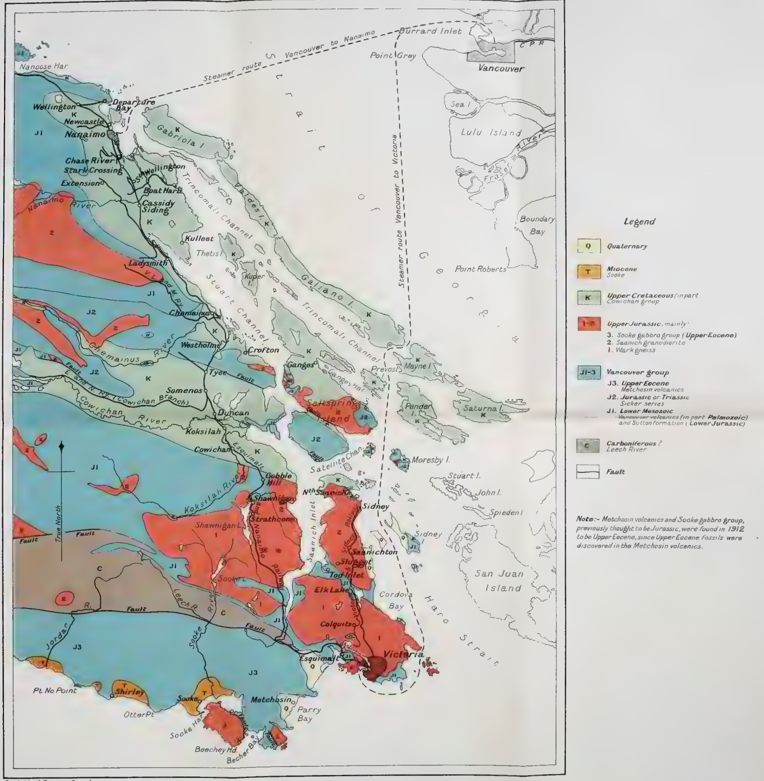

Geological Survey, Canada

Route map between **Victoria** and **Nanaimo**

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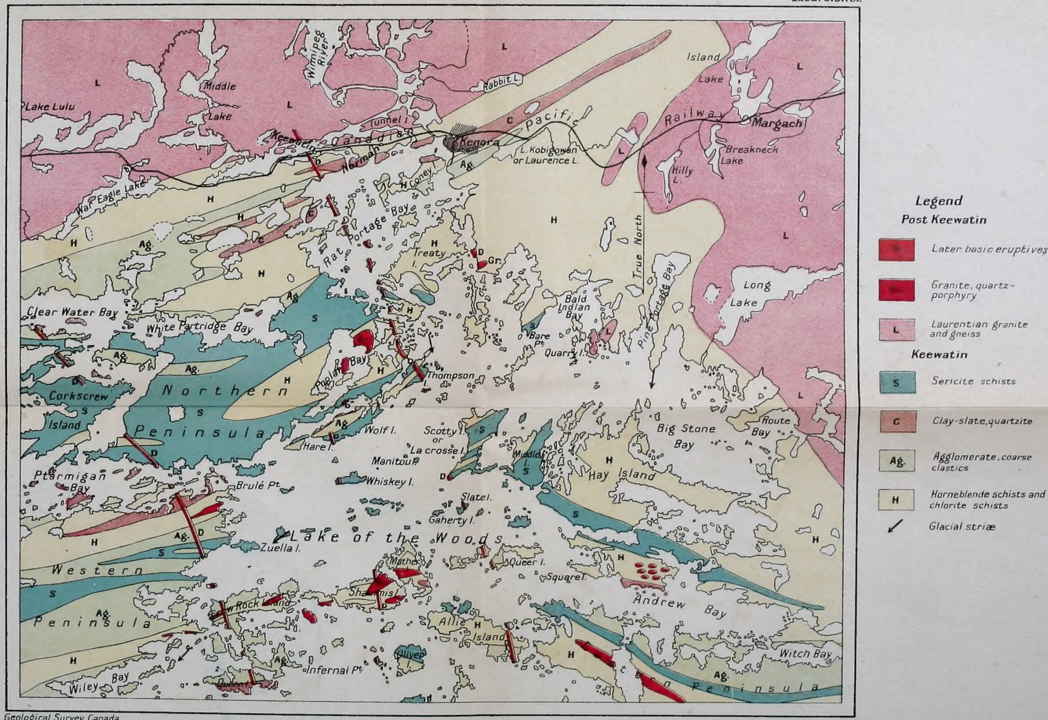
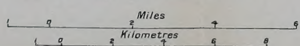


Route map, Lake of the Woods



Victoria and Vicinity